# FOUR WATERFLOODING PROJECTS IN WASHINGTON AND NOWATA COUNTIES, OKLA., 1959

**BY J. P. POWELL**

• • • • • • • • • **Information Circular 7896**

UNITED STATES DEPARTMENT OF THE INTERIOR
Fred A. Seaton, Secretary
BUREAU OF MINES
Marling J. Ankeny, Director

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The work upon which this report is based was done under a cooperative agreement between the Bureau of Mines, U. S. Department of the Interior, and the State of Oklahoma.

1959

**The Library of Congress has cataloged this publication as follows:**

**Powell, John P**

Four waterflooding projects in Washington and Nowata Counties, Okla., 1959. [Washington] U. S. Dept. of the Interior, Bureau of Mines, 1959.

ii, 34 p. illus., maps, tables. 27 cm. (U. S. Bureau of Mines. Information circular 7896)

Bibliographical footnotes.

1. Oil field flooding—Oklahoma—Washington Co. 2. Oil field flooding—Oklahoma—Nowata Co. I. Title. (Series)

[TN295.U4 no. 7896] Int 59-47

U. S. Dept. of the Interior. Library
for Library of Congress

## CONTENTS

Page

Introduction and summary........................................ 1
Acknowledgments................................................. 2
Discussion of individual projects............................... 4
    Van Dall Bros. Post Oak project............................. 4
        History before flooding................................. 4
        Method of completing and operating wells................ 4
        Source and treatment of water........................... 7
        Results of flooding..................................... 8
    Texas Natural & Layton Oil Co. Dewey flood project.......... 9
        History before flooding................................. 11
        Method of completing and operating wells................ 11
        Source and treatment of water........................... 11
        Results of flooding..................................... 13
    Wellsville Oil Co. & Oil Recovery Corp. ORCO process K. & S. project....................................... 17
        History before flooding................................. 17
        Method of completing and operating wells................ 17
        Source and treatment of water........................... 20
        Manufacture of carbon dioxide........................... 21
        Results of flooding..................................... 23
    American Climax Petroleum Corp. Childers Unit project...... 25
        History before flooding................................. 25
        Method of completing and operating wells................ 25
        Source and treatment of water........................... 30
        Results of flooding..................................... 32

## ILLUSTRATIONS

Fig.

1. Map showing location of four waterflooding projects in Washington and Nowata Counties, Okla., Jan. 1, 1959............................................ 3
2. Map and history of production of Van Dall Bros. Post Oak project, Washington County, Okla., Jan. 1, 1959.......................................... 5
3. Results of core analyses of Bartlesville sandstone, Van Dall Bros. Post Oak project, Washington County, Okla........................................ 6

## ILLUSTRATIONS (Con.)

**Fig.** **Page**

4. Map and history of production by waterflooding of Texas Natural & Layton Oil Co. Dewey flood project, Washington County, Okla., Jan. 1, 1959............ 10
5. Results of core analyses of Bartlesville sandstone, Texas Natural & Layton Oil Co. Dewey flood project, Washington County, Okla.................. 12
6. Map and history of production by waterflooding and carbon dioxide injection of Wellsville Oil Co. & Oil Recovery Corp. ORCO process K. & S. project, Washington County, Okla., Jan. 1, 1959............ 18
7. Results of core analyses of Bartlesville sandstone, Wellsville Oil Co. & Oil Recovery Corp. ORCO process K. & S. project, Washington County, Okla.. 19
8. Water-treating and CO plant of Wellsville Oil Co. & Oil Recovery Corp. K. & S. project, Washington County, Okla...................................... 22
9. Map and producing history of American Climax Petroleum Corp. Childers unit, Nowata County, Okla., Jan. 1, 1959...................................... 26
10. Individual oil-well testing manifold and tanks, American Climax Petroleum Corp. Childers unit, Nowata County, Okla............................... 28
11. Water-treating plant and Automatic Custody Transfer System, American Climax Petroleum Corp. Childers unit, Nowata County, Okla......................... 29
12. Automatic Custody Transfer System, American Climax Petroleum Corp. Childers unit, Nowata County, Okla............................................. 31

## TABLES

1. Mineral analyses of injection waters, Van Dall Bros. Post Oak project, Washington County, Okla......... 7
2. Mineral analyses of injection waters, Texas Natural & Layton Oil Co. Dewey flood project, Washington County, Okla...................................... 14
3. Mineral analyses of injection waters, Wellsville Oil Co. & Oil Recovery Corp. ORCO process K. & S. project, Washington County, Okla.................. 21
4. Mineral analyses of injection waters, American Climax Petroleum Corp. Childers unit project, Nowata County, Okla............................... 32

# FOUR WATERFLOODING PROJECTS IN WASHINGTON AND NOWATA COUNTIES, OKLA., 1959[1]

by

J. P. Powell[2]

## INTRODUCTION AND SUMMARY

Since the beginning of waterflooding in the Midcontinent area, the Bureau of Mines has published many reports[3-6] describing in detail the results obtained on individual waterflooding projects in the area. These are intended as guides for operators in the selection of well-spacing, water-treating, and other techniques, as well as an indication of the results being obtained in waterflooding in various areas, fields, and horizons.

In addition, Bureau personnel has arranged a tour of selected waterflooding projects each year for the past several years so that actual operating conditions may be observed and an additional opportunity provided for exchanging information. Each of these tours has been supplemented by a published report[7-11] describing in detail the projects visited. With these reports, those making the tour are in a better position to benefit from their observations.

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[1] Work on manuscript completed March 1959.

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[3] Grandone, Peter, History of Water-Flooding of Oil Sands in Kansas: Bureau of Mines Rept. of Investigations 3761, 1944, 146 pp.

[4] Powell, J. P., and Eakin, J. L., Water Flooding in the Oil Fields of Anderson, Franklin, Linn, and Miami Counties, Kans.: Bureau of Mines Rept. of Investigations 4991, 1953, 111 pp.

[5] Powell, J. P., Survey of Water-Flooding Projects in Allen, Bourbon, Crawford, Labette, and Neosho Counties, Kans.: Bureau of Mines Rept. of Investigations 5317, 1957, 172 pp.

[6] Powell, J. P., and Johnston, Kenneth H., A Survey of Oil Production in Oklahoma by Water Flooding. Part I. Nowata, Rogers, and Craig Counties: Bureau of Mines Rept. of Investigations 4831, 1952, 160 pp. A Survey of Oil Production in Oklahoma by Water Flooding. Part II. Counties Other Than Nowata, Rogers, and Craig: Bureau of Mines Rept. of Investigations 4832, 1951, 142 pp.

This report is intended for distribution in connection with the 1959 spring tour arranged in Washington and Nowata Counties, Okla., by Bureau of Mines personnel.

Waterflooding was first tried in Nowata County in 1931 and in Washington County, Okla. in 1937. Although the first projects in each county were not satisfactory, more than 90 percent of the 10 million barrels of oil produced annually in these two counties is due to waterflooding. New production methods or more efficient and less costly methods of operation interest all petroleum producers.

This report describes in detail four projects in Washington and Nowata Counties, Okla., including the first project in this area employing carbonated water. Figure 1 shows the four projects in Washington and Nowata Counties, Okla.

On one of the projects, high-pressure carbon dioxide is being injected with water into the input wells. Another project uses electric submersible pumps and automatic custody transfer of oil production to minimize operation costs. A third project treats and injects the produced brine into a separate area of the project, whereas another project uses a unique water-conditioning method.

The discussions of the individual projects include information on their early history, the source and treatment of water used for flooding, oil production-decline curves, typical core and water analyses, and results of waterflooding.

## ACKNOWLEDGMENTS

This report on four waterflooding projects in Nowata and Washington Counties, Okla., was prepared by the Bureau of Mines, United States Department of the Interior, under a cooperative agreement with the State of Oklahoma.

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[7] Riggs, C. H., and Smith, William C., Water Flooding of Oil Sands in Washington County, Okla.: Bureau of Mines Rept. of Investigations 4795, 1951, 16 pp.

[8] Powell, J. P., and Eakin, J. L., Water Flooding in Nowata County, Okla. Oil Fields: Bureau of Mines Rept. of Investigations 4896, 1952, 49 pp.

[9] Eakin, J. L., Recent Developments in Water Flooding in Nowata County, Okla. Oil Fields, 1954-55: Bureau of Mines Rept. of Investigations 5134, 1955, 49 pp.

[10] Powell, J. P., Water Flooding of Oil Sands in Butler and Greenwood Counties, Kans.: Bureau of Mines Inf. Circ. 7750, 1956, 42 pp. Some Recent Developments in Waterflooding in Washington County, Okla. 1956-57: Bureau of Mines Inf. Circ. 7787, 1957, 35 pp.

[11] Powell, J. P., Eakin, J. L., Johnston, K. H., and Riggs, C. H., Four Waterflooding Projects in Cowley County, Kans., 1958: Bureau of Mines Inf. Circ. 7831, 1958, 27 pp.

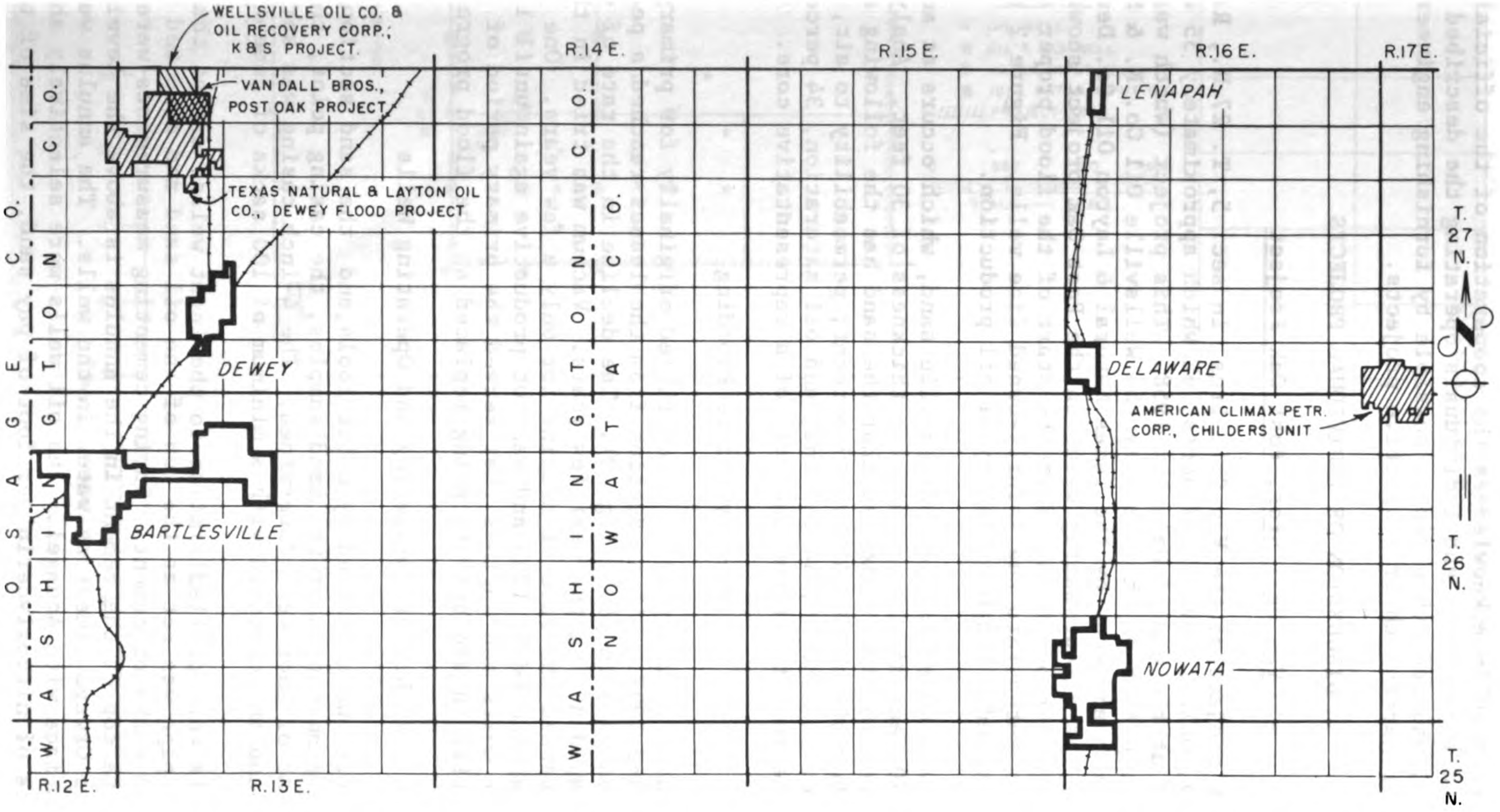
WELLSVILLE OIL CO. & OIL RECOVERY CORP.; K & S PROJECT.
VAN DALL BROS., POST OAK PROJECT
TEXAS NATURAL & LAYTON OIL CO., DEWEY FLOOD PROJECT
R.12 E.
R.13 E.
R.14 E.
R.15 E.
R.16 E.
R.17 E.
T. 27 N.
T. 26 N.
T. 25 N.
O S A G E C O.
W A S H I N G T O N C O.
N O W A T A C O.
DEWEY
BARTLESVILLE
LENAPAH
DELAWARE
NOWATA
AMERICAN CLIMAX PETR. CORP., CHILDERS UNIT
N

FIGURE 1. - Map Showing Location of Four Waterflooding Projects in Washington and Nowata Counties, Okla., Jan. 1, 1959.

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The writer gratefully acknowledges the cooperation of the officials and employees of the oil companies and individuals operating the described waterflooding projects, who made this report possible by furnishing engineering and statistical data regarding their respective projects.

## DISCUSSION OF INDIVIDUAL PROJECTS

### Van Dall Bros. Post Oak Project

The Post Oak project of the Van Dall Bros. in sec. 5, T. 27 N., R. 13 E., Washington County, Okla., covers 240 acres, of which approximately 35 acres was being flooded at the end of December 1958. This project (which was begun August 2, 1957) is offset on the north by the Wellsville Oil Co. K. & S. project and on the south and west by the Texas Natural & Layton Oil Co. Dewey project. Some of the oil-producing wells on the Post Oak project showed an increased rate of oil production before the start of the flood proper as a result of water injected into the jointly-owned line wells. Figure 2 shows a map of the project and a graphic history of oil production.

The formation flooded is the Bartlesville sand, which occurs at an average depth of 1,270 feet and has an average thickness of 30 feet. Analyses of cores taken before flooding indicated that the sand has the following average reservoir characteristics: Porosity, 17 percent; permeability to air, 43 millidarcys; water saturation, 44 percent; and oil saturation, 34 percent. Figure 3 shows the results of the analysis of a representative core.

#### History Before Flooding

Leases included in the project were drilled originally for primary production in 1906 and 1907. Oil production from the leases reached a peak rate of about 64,000 barrels in 1909 (fig. 2). The decline in the rate of oil production was rapid during the next few years. Vacuum was tried in the late 1920's but it retarded the rate of decline for only a few years. One lease was temporarily abandoned in 1935 and was not productive again until 1942. Old central power units and engines that served the primary period of oil production are still in use but are being replaced as the flood progresses.

#### Method of Completing and Operating Wells

The input wells were drilled by cable tools,and the sand section was cored. Based on examination of the sand samples, the casing point, the pay sand, and the size of shot were determined. The 4-inch casing was set at the top of the pay sand and cemented with a minimum of 100 sacks of cement.

The oil wells were drilled similar to the input wells, except that 5 1/2- or 7-inch pipe was set at the top of the oil sand and cemented with approximately 100 sacks of cement. During cementing measurements were taken to assure that the top of the cement in the annulus is above the level of the usually corrosive Oswego limestone water in the wells. The annulus was then filled to the surface with Aquagel. The oil wells were selectively shot with 2 1/2 to 3 quarts of nitroglycerin per foot of pay sand, the size of the shot being based on examination of the sand samples.

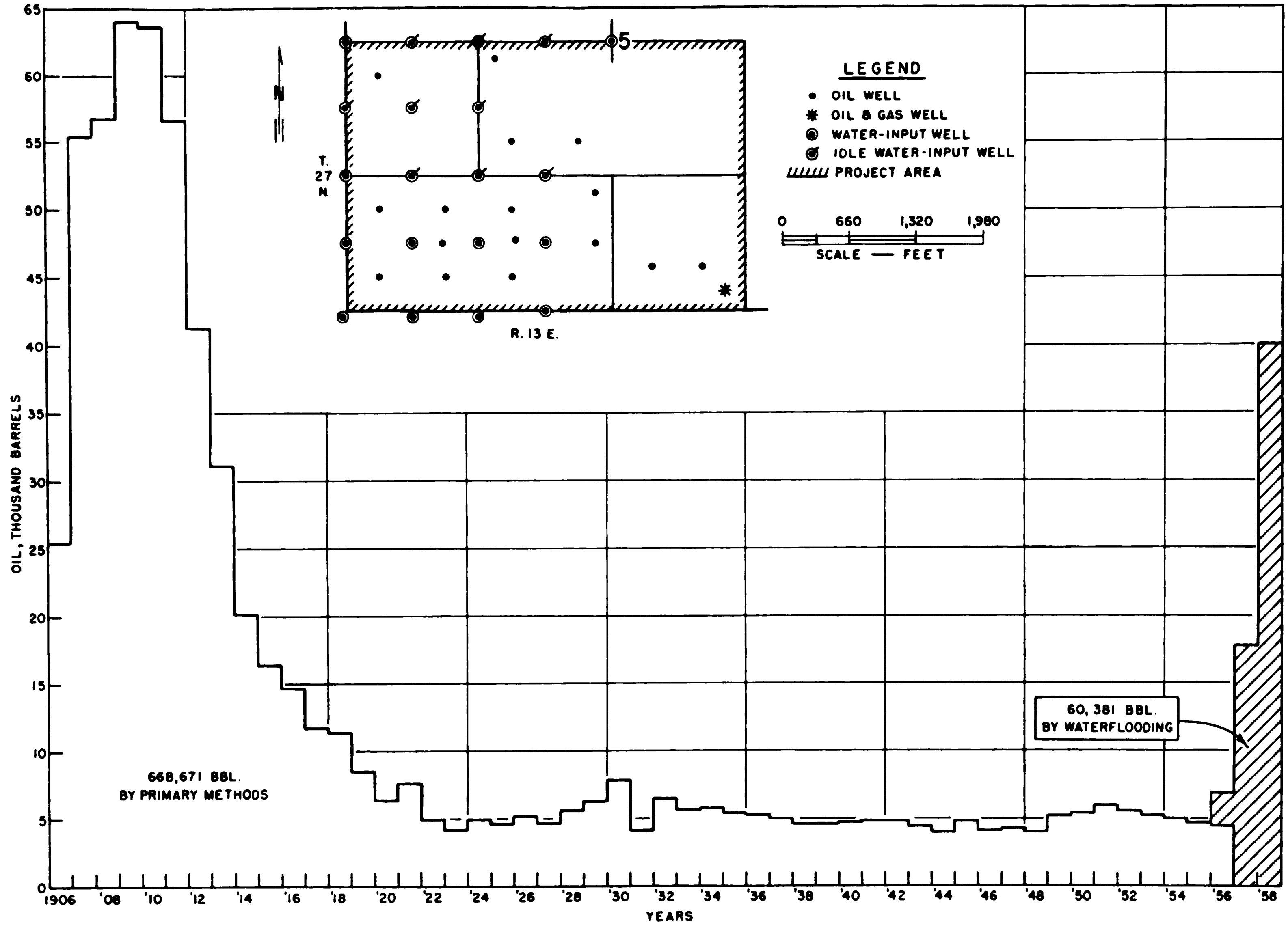

FIGURE 2. - Map and History of Production of Van Dall Bros. Post Oak Project, Washington County, Okla., Jan. 1, 1959.

Original from THE OHIO STATE UNIVERSITY

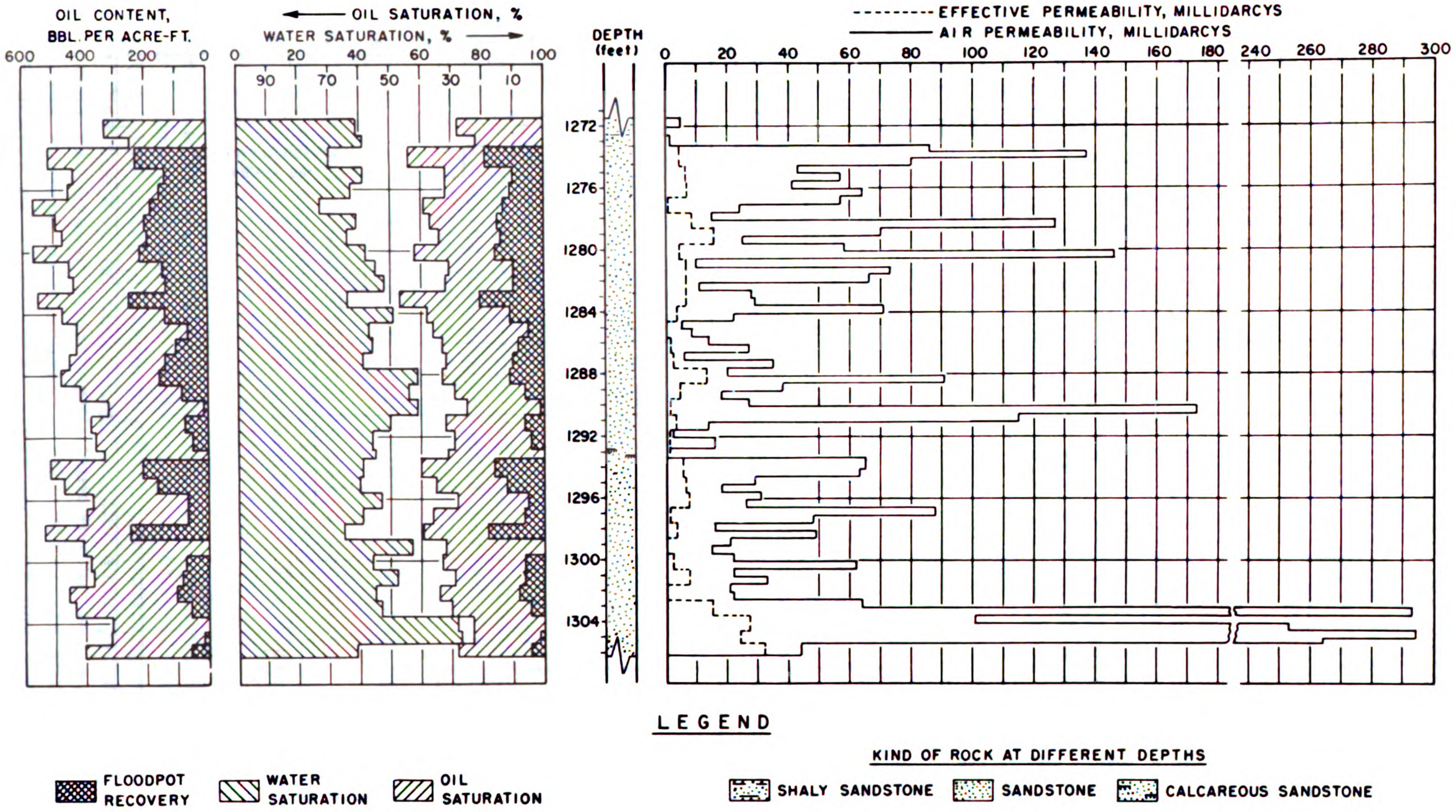

FIGURE 3. - Results of Core Analyses of Bartlesville Sandstone, Van Dall Bros. Post Oak Project, Washington County, Okla.

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As the oil wells are affected by the advancing flood, they are equipped for pumping with individual electric pumping units. Most of these units are set on raised welded-pipe platforms which will permit lease operations along the river to continue during high water.

## Source and Treatment of Water

Fresh water from the Caney River is treated and used as the principal supply for flooding. A centrifugal pump delivers the raw water through a 5-inch line to a 70-barrel steel agitator tank. This tank has been equipped with a set of custom-built paddles or blades powered by an electric motor with a speed reducer. It provides especially efficient mixing of the chemicals added for treating. The produced brine from the lease tanks also flows into the tank. The treated water is permitted to flow into two settling ponds divided by an earthen baffle. Although each pond has a separate set of baffles, the two are joined by a 12-inch cement conduit to provide a total capacity of about 40,000 barrels of water under operating conditions. The treated water is pumped through a 6-foot-diameter, closed-type filter and into a 500-barrel wooden clear-water tank. The filter is filled with graded sand and gravel and backwashed as needed, usually once a week by a centrifugal backwash pump. Treated water is drawn from the clear-water tank and pumped into the field-distribution system at a pressure of 480 p.s.i. by a triplex pump. A special regulator controls the field pressure. It prevents subjecting the input wells to varying pressures, either above or below a predetermined setting by slowing or speeding the water pump, thereby assuring a constant rate of water injection into the wells.

Plans are being considered for confining the produced brines in a separate system for treating and injection into segregated wells. Table 1 shows mineral analyses of the injection waters.

TABLE 1. - Mineral analyses of injection waters, Van Dall Bros. Post Oak project, Washington County, Okla.

| Ion or radical | River water | | Produced brine | | Treated water | |
|---|---|---|---|---|---|---|
| | P.p.m. | Reacting values, percent (Palmer) | P.p.m. | Reacting values, percent (Palmer) | P.p.m. | Reacting values, percent (Palmer) |
| Calcium (Ca) | 79 | 23.65 | 3,400 | 6.85 | 91 | 8.52 |
| Magnesium (Mg) | 14 | 6.90 | 1,040 | 3.46 | 38 | 5.85 |
| Sodium (Na) | 74 | 19.45 | 22,600 | 39.69 | 440 | 35.63 |
| Carbonate ($CO_3$) | 0 | 0 | 0 | 0 | 0 | 0 |
| Bicarbonate ($HCO_3$) | 217 | 21.36 | 163 | .11 | 187 | 5.76 |
| Sulfate ($SO_4$) | 26 | 3.24 | 0 | 0 | 76 | 2.96 |
| Chloride (Cl) | 150 | 25.40 | 43,800 | 49.89 | 780 | 41.28 |
| Total solids | 560 | 100.00 | 71,003 | 100.00 | 1,612 | 100.00 |
| Hydrogen sulfide ($H_2S$) | None | | None | | None | |
| Barium (Ba) | do. | | 479 p.p.m. | | do. | |
| Specific gravity, 60° F. | 1.002 | | 1.048 | | 1.002 | |

## Results of Flooding

This project is too new to evaluate properly, however, based on the results of water injection into line wells and into a few completed 5-spot patterns, good oil recoveries should be obtained from the intensively flooded areas. An expansion program is to begin after the operational tests on the water plant have been completed. More than 60,000 barrels of waterflood oil had been recovered from the project to January 1, 1959. This recovery is equivalent to 252 barrels of oil per acre, with a cumulative water-injected to oil-produced ratio of 6 : 1.

## Summary of Operations

### • Van Dall Bros. Post Oak project
### Bartlesville-Dewey field, Washington County, Okla.

Location - sec. 5, T. 27 N., R. 13 E.
Sand flooded - Bartlesville.
Depth to top of sand - 1,270 feet.
Average sand thickness - 30 feet.
Productive area - 240 acres.
Area flooded - 35 acres.
Well pattern - 5-spot (660 x 660 ft.)

Type of water - fresh.
Type of system - open.
First water injection - Aug. 2, 1957.
First oil increase - September 1957.
Gravity of oil - 35° API.
Viscosity of oil - 6 cp. at 100° F.

Oil production by years, bbl. (240 acres)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1906 | 25,457 | 1920 | 6,353 | 1934 | 5,740 | 1948 | 4,049 |
| 1907 | 55,420 | 1921 | 7,348 | 1935 | 5,443 | 1949 | 5,257 |
| 1908 | 56,700 | 1922 | 4,903 | 1936 | 5,302 | 1950 | 5,440 |
| 1909 | 64,085 | 1923 | 4,189 | 1937 | 5,003 | 1951 | 6,050 |
| 1910 | 63,716 | 1924 | 4,891 | 1938 | 4,641 | 1952 | 5,606 |
| 1911 | 56,672 | 1925 | 4,648 | 1939 | 4,604 | 1953 | 5,330 |
| 1912 | 41,262 | 1926 | 5,165 | 1940 | 4,757 | 1954 | 5,031 |
| 1913 | 31,125 | 1927 | 4,645 | 1941 | 4,851 | 1955 1/ | 4,724 |
| 1914 | 20,182 | 1928 | 5,625 | 1942 | 4,868 | 1956 | 2/ 6,990 |
| 1915 | 16,365 | 1929 | 6,221 | 1943 | 4,471 | 1957 3/ | 17,827 |
| 1916 | 14,678 | 1930 | 7,887 | 1944 | 4,049 | 1958 | 40,064 |
| 1917 | 11,791 | 1931 | 4,184 | 1945 | 4,800 | | |
| 1918 | 11,427 | 1932 | 6,500 | 1946 | 4,166 | | |
| 1919 | 8,584 | 1933 | 5,693 | 1947 | 4,273 | | |

1/ Flooding was begun on adjacent leases.

2/ Includes 2,490 barrels of oil estimated recovered from water injected into line wells during 1956.

3/ Water injection was begun on the project.

## Summary of waterflood performance

| Date | Acres flooded | Active oil wells1/ | Active input wells2/ | Oil recovery, bbl. per acre (240 acres) | Cumulative water injected-oil produced ratio |
|---|---|---|---|---|---|
| 1955-1956.......... | 5 | 5 | 3 | 3/10 | - |
| Dec. 31, 1957...... | 7 | 10 | 3 | 95 | 3 |
| Dec. 31, 1958...... | 35 | 16 | 10 | 252 | 6 |

1/ Includes old wells.

2/ Includes line wells.

3/ Includes 2,490 barrels of oil estimated recovered from water injected into line wells during 1956.

| | Bbl. |
|---|---|
| Oil recovered by primary methods (240 acres)....................... | 668,671 |
| Oil recovered per acre by primary methods (240 acres)............. | 2,786 |
| Oil recovered by waterflood to January 1, 1959..................... | 60,381 |
| Oil recovered per acre by waterflooding to January 1, 1959 (240 acres)................................................... | 252 |
| Total water injected to January 1, 1959........................... | 342,076 |
| Total oil recovered to January 1, 1959............................ | 729,052 |

## Monthly record of water injected and oil produced, bbl.

| | 1957 | | 1958 | |
|---|---|---|---|---|
| Month | Water injected | Oil produced | Water injected | Oil produced |
| January.................... | No record of water injected into line wells | 941 | 18,476 | 2,852 |
| February................... | | 952 | 16,968 | 2,656 |
| March...................... | | 1,024 | 17,856 | 2,523 |
| April...................... | | 1,100 | 20,007 | 2,750 |
| May........................ | | 1,174 | 22,692 | 3,090 |
| June....................... | | 615 | 26,310 | 3,258 |
| July....................... | | 1,457 | 25,916 | 3,459 |
| August..................... | | 1,325 | 26,784 | 3,477 |
| September.................. | 7,260 | 1,811 | 25,050 | 3,720 |
| October.................... | 15,066 | 2,191 | 28,706 | 3,839 |
| November................... | 15,150 | 2,479 | 28,500 | 4,323 |
| December................... | 19,375 | 2,758 | 27,960 | 4,117 |
| Total................ | 56,851 | 17,827 | 285,225 | 40,064 |

## The Texas Natural & Layton Oil Co. Dewey Flood Project

This project, begun in February 1953 as a pilot operation, is in secs. 6, 7, 8, and 17, T. 27 N., R. 13 E. and sec. 12, T. 27 N., R. 12 E., Washington County, Okla. The leased area of the project includes 1,220 acres (unitized area), of which 985 had been developed for flooding by January 1, 1959. Fresh water is used for flooding, but produced brine is treated in a separate system and reinjected into wells in a segregated area. Figure 4 shows a map of the project and a graphical history of the waterflooding production.

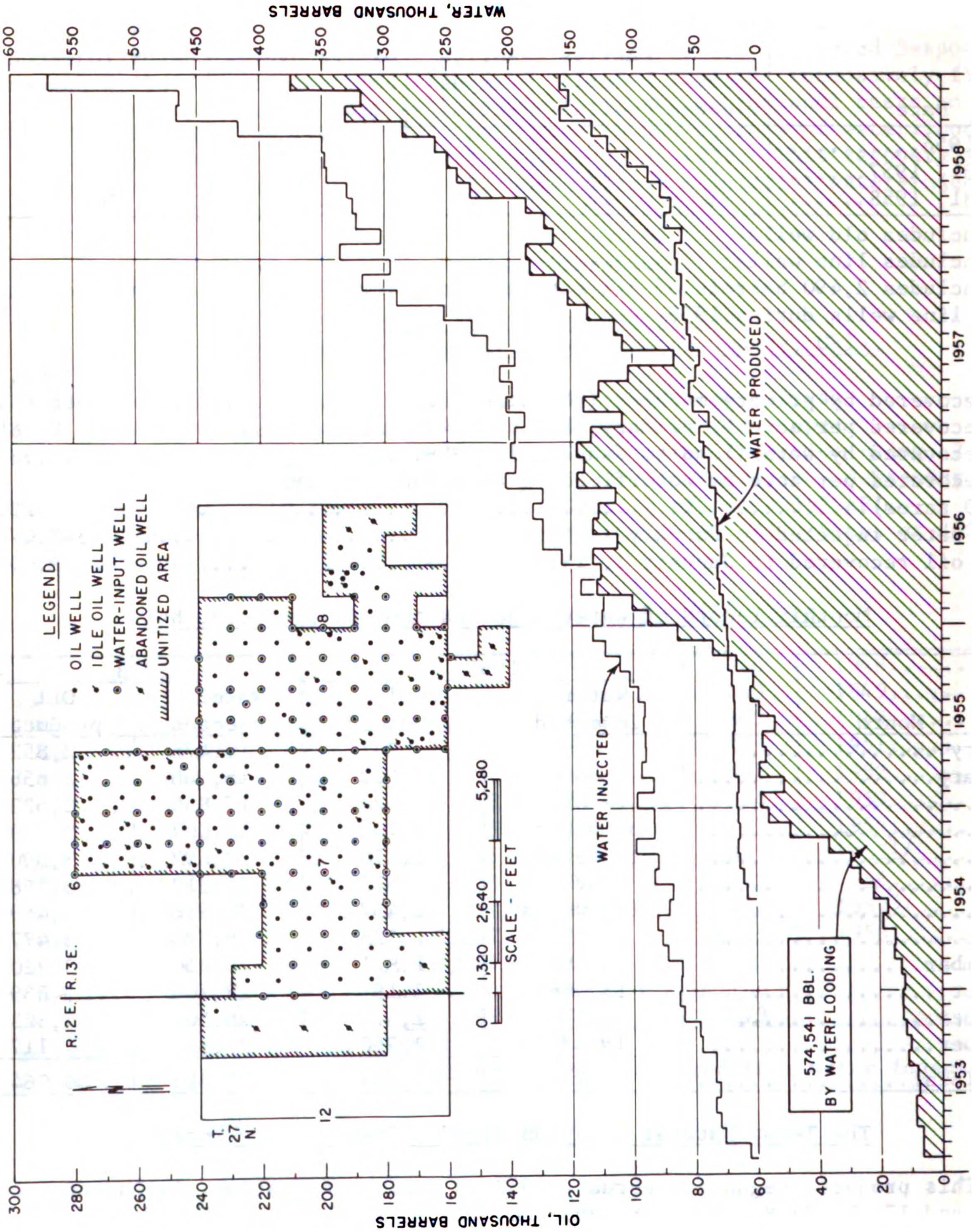

FIGURE 4. - Map and History of Production by Waterflooding of Texas Natural & Layton Oil Co. Dewey Flood Project, Washington County, Okla., Jan. 1, 1959.

The formation flooded is the Bartlesville sand at an average depth of 1,280 feet and has an average thickness of 28 feet. Figure 5 shows the results of the analysis of a representative core of the formation. This and other cores taken before flooding indicated that the reservoir sand had the following average reservoir conditions: Porosity, 17 percent; permeability to air, 44 millidarcys; water saturation, 42 percent; oil saturation, 32 percent.

## History Before Flooding

The primary drilling occurred in 1906 and 1907. Production was by primary methods, although an attempt to use vacuum in the late 1920's proved uneconomical. Statistical data for this period was not readily available.

## Method of Completing and Operating Wells

Input wells were completed with 2-inch tubing and rag packers set at the top of the sand, and each well was cemented with 20 sacks of cement. During the pilot operation the meters and control valves were set at the wellheads. As the flood was expanded, a modified header system was designed for each lease, so that most of the meters were centrally located. Input wells were shot, each with 1 1/2 quarts of nitroglycerin per foot of pay sand. Initial daily water injection rates were approximately 2 1/2 barrels of water per foot of pay sand. The rates have been increased gradually to about 7 1/2 barrels of water per foot of pay sand.

The producing wells were completed with 4-inch pipe and rag packers set about 2 feet into the pay sand; each was cemented with 20 sacks of cement. The wells were cored to aid in the setting of the pipe and design of the shot. The oil wells were shot with 2 1/2 quarts of nitroglycerin per foot of pay sand. The oil wells were completed for use in crossflooding during the final stages of the flooding operation. The wells were equipped with tubing and rods for pumping by individual electric pumping units. Privately owned electric transmission lines permit economical distribution of electric power to all pumping units and water plants.

## Source and Treatment of Water

A 4-inch centrifugal pump powered by an electric motor pumps fresh water from the Caney River for flooding. This pumping unit is constructed so that the action of a float switch connected to an electrically operated winch will automatically raise the unit if the water level of the river should rise. From the river the water is pumped through a treating house, where lime and aluminum sulfate are added. The water then flows along a 30-inch mixing flume into a 150,000-barrel settling pond, divided by two baffles. Enough detention time is allowed for efficient coagulation and settling of the products of the chemical reactions. From the settling pond a centrifugal pump forces the water through a 10-foot-diameter pressure filter. The filter is of the closed type and is filled with sand and gravel. After filtration the water flows into two 500-barrel, closed, steel tanks which serve as clear-water tanks. The interiors of the tanks are plastic-coated to minimize corrosion. Float switches at the high and low fluid levels control the pumps for continuous

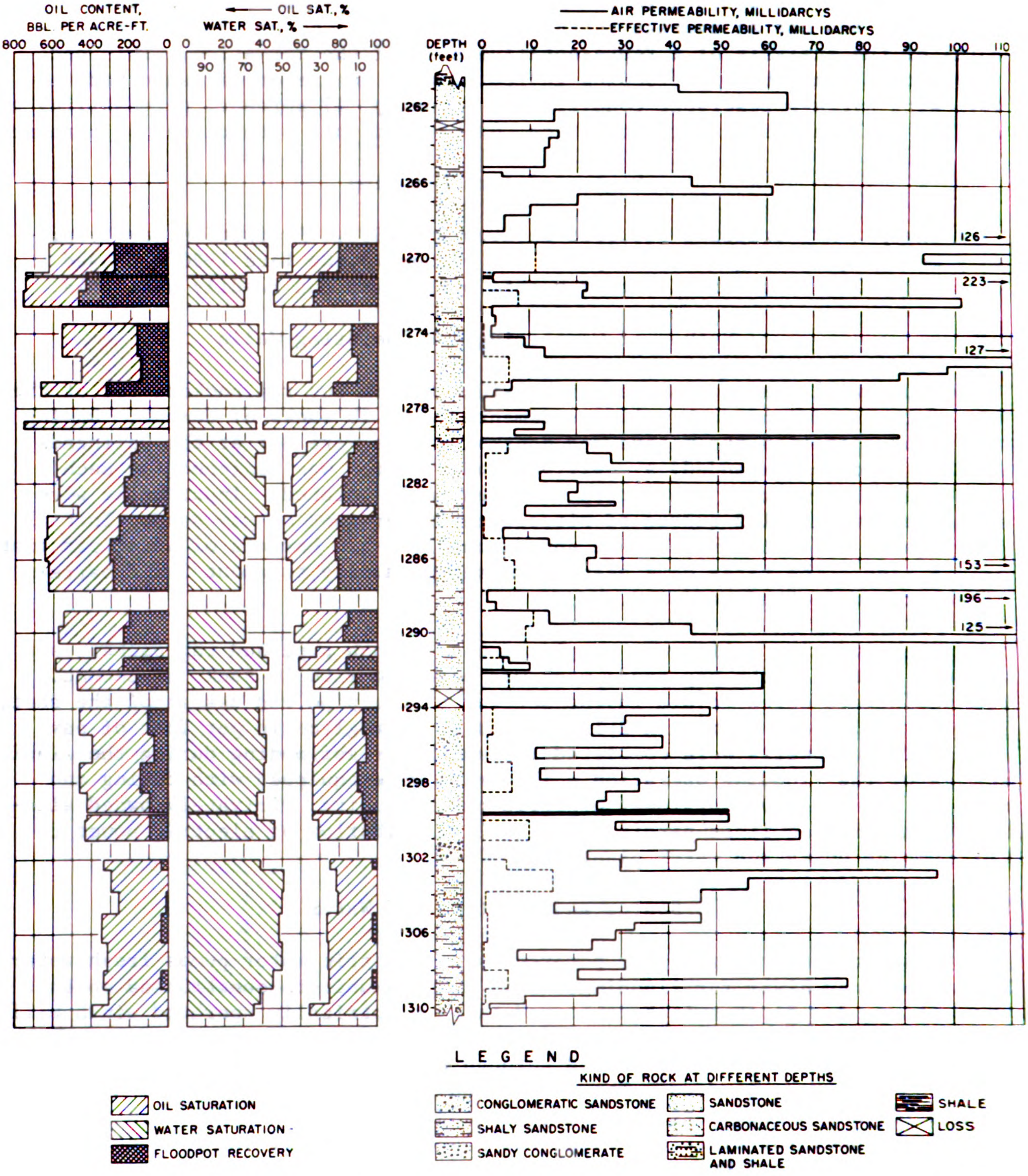

FIGURE 5. - Results of Core Analyses of Bartlesville Sandstone, Texas Natural & Layton Oil Co. Dewey Flood Project, Washington County, Okla.

operation of the plant. Two triplex pumps force the filtered, treated water into the distribution system at a pressure of 700 p.s.i.

The project has three complete pumping plants, two for fresh water and one for the produced brine. Each plant is tied into a common water system, so that operations can be continued if one or more plants become inoperative.

The produced brine is separated from the oil at a consolidated tank battery and then flows into a small skimming pond of about 500-barrel capacity, where final traces of oil are removed. Lime is added in a series of treating and mixing ponds, and the brine is aerated and allowed to flow into the settling basins. Here the products of chemical reactions are allowed to settle out. A centrifugal pump forces the water through two closed, pressure-type filters of sand and gravel into a 200-barrel wooden clear-water tank. From the clear-water tanks, the brine is forced by two triplex pumps into the distribution system at a plant pressure of 700 p.s.i. The treated brine is injected into selected leases; however, the plant can be connected to the others in an emergency. Table 2 shows mineral analyses of the injection waters.

Detergents used in the water-conditioning process have been found to increase the rate of injectivity about 20 percent.

## Results of Flooding

A pilot waterflooding operation of about 90 acres was used to evaluate the possibilities of the leased area. To January 1, 1959, over 2,940 barrels of oil had been recovered from the pilot area. The property was not developed as a unit until the pilot test proved profitable. As a result, the project was not expanded for nearly 2 years. To January 1, 1959, the project was developed to cover 985 acres and has recovered more than one-half million barrels of oil from injection of nearly 12 million barrels of water. The rate of oil production has not yet reached a peak, and it is estimated that approximately 3.9 million barrels of oil should be recovered when the entire project has been flooded. A modified delayed drilling of the producing wells is expected to add to the recovery.

TABLE 2. - Mineral analyses of injection waters, Texas Natural & Layton Oil Co. Dewey flood project, Washington County, Okla.

| Ion or radical | River water | | Treated river water | | Produced brine | | Treated produced brine | |
|---|---|---|---|---|---|---|---|---|
| | P.p.m. | Reacting values, percent (Palmer) | P.p.m. | Reacting values, percent (Palmer) | P.p.m. | Reacting values, percent (Palmer) | P.p.m. | Reacting values, percent (Palmer) |
| Calcium (Ca).............. | 79 | 23.65 | 77 | 29.21 | 3,700 | 7.54 | 3,500 | 7.38 |
| Magnesium (Mg)............ | 14 | 6.90 | 8 | 5.36 | 850 | 2.85 | 820 | 2.85 |
| Sodium (Na)............... | 74 | 19.45 | 43 | 15.43 | 22,300 | 39.61 | 21,600 | 39.77 |
| Carbonate ($CO_3$)........... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bicarbonate ($HCO_3$)........ | 217 | 21.36 | 216 | 5.94 | 234 | .16 | 227 | .16 |
| Sulfate ($SO_4$)............. | 26 | 3.24 | 44 | 7.59 | 0 | 0 | 0 | 0 |
| Chloride (Cl)............. | 150 | 25.40 | 157 | 36.47 | 43,300 | 49.84 | 41,800 | 49.84 |
| Total solids......... | 560 | 100,00 | 545 | 100.00 | 70,384 | 100.00 | 67,947 | 100.00 |
| Hydrogen sulfide ($H_2S$).... | None | | None | | None | | None | |
| Barium (Ba)............... | do. | | do. | | 415 p.p.m. | | 384 p.p.m. | |
| Specific gravity.......... | 1.002 | | 1.002 | | 1.052 | | 1.051 | |

Original from THE OHIO STATE UNIVERSITY

## Summary of Operations

### The Texas Natural & Layton Oil Co.
### Dewey flood, Washington County, Okla.

Location - secs. 6, 7, 8, and 17,
T. 27 N., R. 13 E. and sec. 12,
T. 27 N., R. 12 E.
Sand flooded - Bartlesville.
Depth to top of sand - 1,280 feet.
Average sand thickness - 28 feet.
Productive area - 1,220 acres.
Area flooded - 985 acres.
Well pattern - 5-spot (660 x 660 ft.)

Type of water - fresh.
Type of system - open.
First water injected - Feb. 23, 1953.
First oil increase - July 1954.
Gravity of oil - 34° API.
Viscosity of oil - 6.6 cp. at 94° F.

Primary production data not available.

### Summary of waterflood performance

| Date | Acres flooded | Active oil wells | Active input wells | Oil recovered, bbl. per acre | Cumulative water injected-oil produced ratio |
|---|---|---|---|---|---|
| Dec. 31, 1953....... | 90 | 19 | 17 | 117 | 38 |
| Dec. 31, 1954....... | 90 | 19 | 17 | 465 | 32 |
| Dec. 31, 1955....... | 350 | 24 | 23 | 334 | 22 |
| Dec. 31, 1956....... | 400 | 28 | 35 | 622 | 18 |
| Dec. 31, 1957....... | 480 | 48 | 51 | 797 | 19 |
| Dec. 31, 1958....... | 985 | 104 | 112 | 583 | 21 |

| | Bbl. |
|---|---|
| Total water injected to January 1, 1959......................... | 11,883,170 |
| Total water produced to January 1, 1959......................... | 2,625,345 |
| Oil recovered by waterflooding (985 acres) to January 1, 1959.... | 574,541 |
| Oil recovered per acre by waterflooding (985 acres) to January 1, 1959.................................................. | 583 |

Monthly record of water injected, oil and water produced, bbl.

| Month | 1953 |  |  | 1954 |  |  |
|---|---|---|---|---|---|---|
|  | Water injected | Oil produced | Water produced | Water injected | Oil produced | Water produced |
| January....... |  |  |  | 61,084 | 1,200 | - |
| February...... | 5,817 | 676 |  | 61,043 | 1,307 | - |
| March......... | 25,942 | 670 |  | 73,555 | 1,595 | - |
| April......... | 29,960 | 856 |  | 77,883 | 1,518 | - |
| May........... | 33,639 | 886 |  | 80,110 | 1,905 | - |
| June.......... | 30,048 | 784 |  | 71,224 | 1,754 | - |
| July.......... | 32,801 | 837 |  | 66,988 | 2,217 | 8,618 |
| August........ | 34,217 | 1,125 |  | 83,401 | 2,663 | 10,695 |
| September..... | 44,797 | 1,046 |  | 79,523 | 2,981 | 13,830 |
| October....... | 46,276 | 1,166 |  | 99,219 | 3,687 | 14,880 |
| November...... | 59,102 | 1,281 |  | 86,547 | 4,913 | 13,950 |
| December...... | 61,984 | 1,231 |  | 87,084 | 5,618 | 14,911 |
| Total.... | 404,583 | 10,558 |  | 927,661 | 31,358 | 76,884 |
| Month | 1955 |  |  | 1956 |  |  |
| January....... | 96,949 | 5,890 | 16,151 | 124,720 | 9,531 | 25,100 |
| February...... | 83,877 | 5,125 | 14,588 | 123,729 | 10,015 | 26,390 |
| March......... | 94,008 | 5,943 | 17,790 | 141,918 | 11,182 | 29,760 |
| April......... | 90,676 | 5,702 | 18,000 | 128,128 | 11,042 | 30,750 |
| May........... | 89,963 | 5,806 | 18,569 | 163,225 | 11,310 | 32,550 |
| June.......... | 91,742 | 5,417 | 17,760 | 171,733 | 10,542 | 33,750 |
| July.......... | 91,135 | 5,948 | 17,515 | 171,804 | 11,318 | 36,735 |
| August........ | 96,902 | 6,233 | 18,848 | 180,746 | 11,146 | 37,200 |
| September..... | 103,519 | 6,114 | 20,640 | 172,872 | 10,596 | 37,500 |
| October....... | 111,744 | 6,660 | 23,250 | 202,445 | 11,811 | 42,625 |
| November...... | 122,076 | 7,436 | 23,100 | 193,544 | 11,593 | 42,750 |
| December...... | 132,769 | 8,572 | 24,025 | 199,188 | 11,797 | 47,275 |
| Total.... | 1,205,360 | 74,846 | 230,236 | 1,974,052 | 131,883 | 422,385 |
| Month | 1957 |  |  | 1958 |  |  |
| January....... | 195,432 | 11,351 | 46,190 | 335,864 | 13,452 | 64,790 |
| February...... | 187,241 | 10,383 | 42,560 | 303,297 | 12,560 | 60,200 |
| March......... | 201,768 | 11,628 | 50,840 | 321,817 | 12,864 | 74,090 |
| April......... | 196,707 | 11,127 | 53,400 | 325,746 | 13,484 | 69,000 |
| May........... | 206,746 | 10,185 | 48,980 | 329,964 | 15,274 | 77,500 |
| June.......... | 194,910 | 8,666 | 46,500 | 346,426 | 15,688 | 87,000 |
| July.......... | 216,698 | 10,380 | 52,800 | 347,199 | 15,993 | 103,850 |
| August........ | 229,369 | 10,642 | 55,490 | 349,703 | 16,378 | 119,350 |
| September..... | 251,563 | 11,451 | 58,500 | 417,068 | 17,409 | 132,000 |
| October....... | 290,160 | 12,132 | 61,380 | 471,774 | 19,284 | 157,820 |
| November...... | 318,084 | 12,414 | 61,200 | 470,116 | 18,762 | 150,750 |
| December...... | 294,645 | 13,339 | 63,550 | 569,217 | 21,050 | 158,100 |
| Total.... | 2,783,323 | 133,698 | 641,390 | 4,588,191 | 192,198 | 1,254,450 |

## Wellsville Oil Co. and Oil Recovery Corp. ORCO Process, K. & S. Project

The Wellsville Oil Co. as flood operator of a joint venture in which Oil Recovery Corp. has 80 percent of the working interest, began water injection on three leases in secs. 5 and 6, T. 27 N., R. 13 E., Washington County, Okla., in February 1958. The ORCO process, which combines standard waterflooding techniques with injection of carbon dioxide during the fillup and early oil-producing stage of the flooding process, is being used on the K. & S. project. Figure 6 shows a map and the waterflood production history of the project. Since February 1958 nearly 50,000 barrels of oil was recovered from the project, when 190 acres, containing 29 water-input wells and 16 oil wells, was developed.

The formation flooded is the Bartlesville, which occurs at an average depth of 1,300 feet and has an average thickness of 33 feet. Analyses of cores, cut before development of the flood, indicated that the formation had the following average reservoir conditions: Porosity, 18 percent; permeability to air, 50 millidarcys; oil saturation, 32 percent; and water saturation, 41 percent. Figure 7 shows the results of the analysis of a representative core. A sample of the oil taken before water injection began had an API gravity of 33° and a viscosity of 6.3 cp. at 100° F.

### History Before Flooding

The leases were originally drilled in 1905, and production was produced by primary methods until the 1930's, when the wells were abandoned. A few wells were drilled in 1918 in an attempt to develop production from the shallower sands; however, the rate of oil production was not economical, and the wells were abandoned. In 1951 several wells were drilled and cored to evaluate the waterflood potential of the property. In 1954 the K. & S. Drilling Co. began developing a small pilot flood, known as the Bonnie Wilson project. Wells drilled for this project have been recompleted and used in the new flood.

### Method of Completing and Operating Wells

Input wells were drilled to the top of the formation, and the sand was cored but not shot. Each input well was completed with a rag packer on 2 1/2-inch tubing set at the top of the pay sand and cemented with 20 sacks of cement. The compressed carbon dioxide is injected through a string of 3/4-inch pipe hung inside the 2 1/2-inch tubing to a point 3 feet off the bottom of the sand.

In the ORCO flooding process the metered water is pumped down the annulus between the 2 1/2-inch pipe and the 3/4-inch pipe, while the $CO_2$ is injected through the 3/4-inch pipe under pressure. Water and carbon dioxide mix at the sand face in the well bore. The volumes of $CO_2$ and water are controlled for each well in a common meter house and injected proportionately to obtain a predetermined saturation of $CO_2$ in the water at the sand face. Although average injection rates of 7 barrels of water per foot of sand at wellhead pressures of 0 to 700 p.s.i. are usual in this area; the operator is presently

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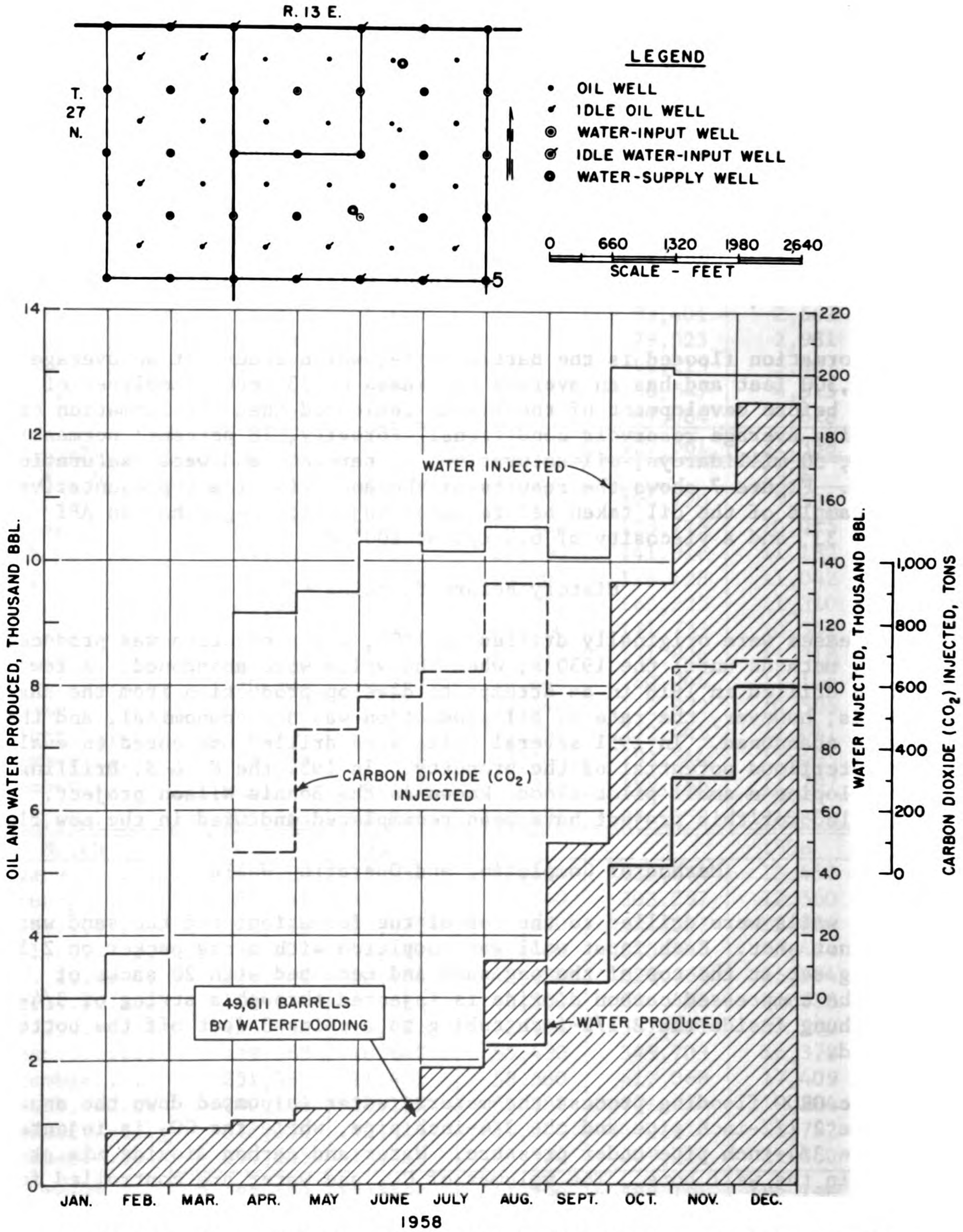

FIGURE 6. - Map and History of Production by Waterflooding and Carbon Dioxide Injection of Wellsville Oil Co. & Oil Recovery Corp. ORCO Process K. & S. Project, Washington County, Okla., Jan. 1, 1959.

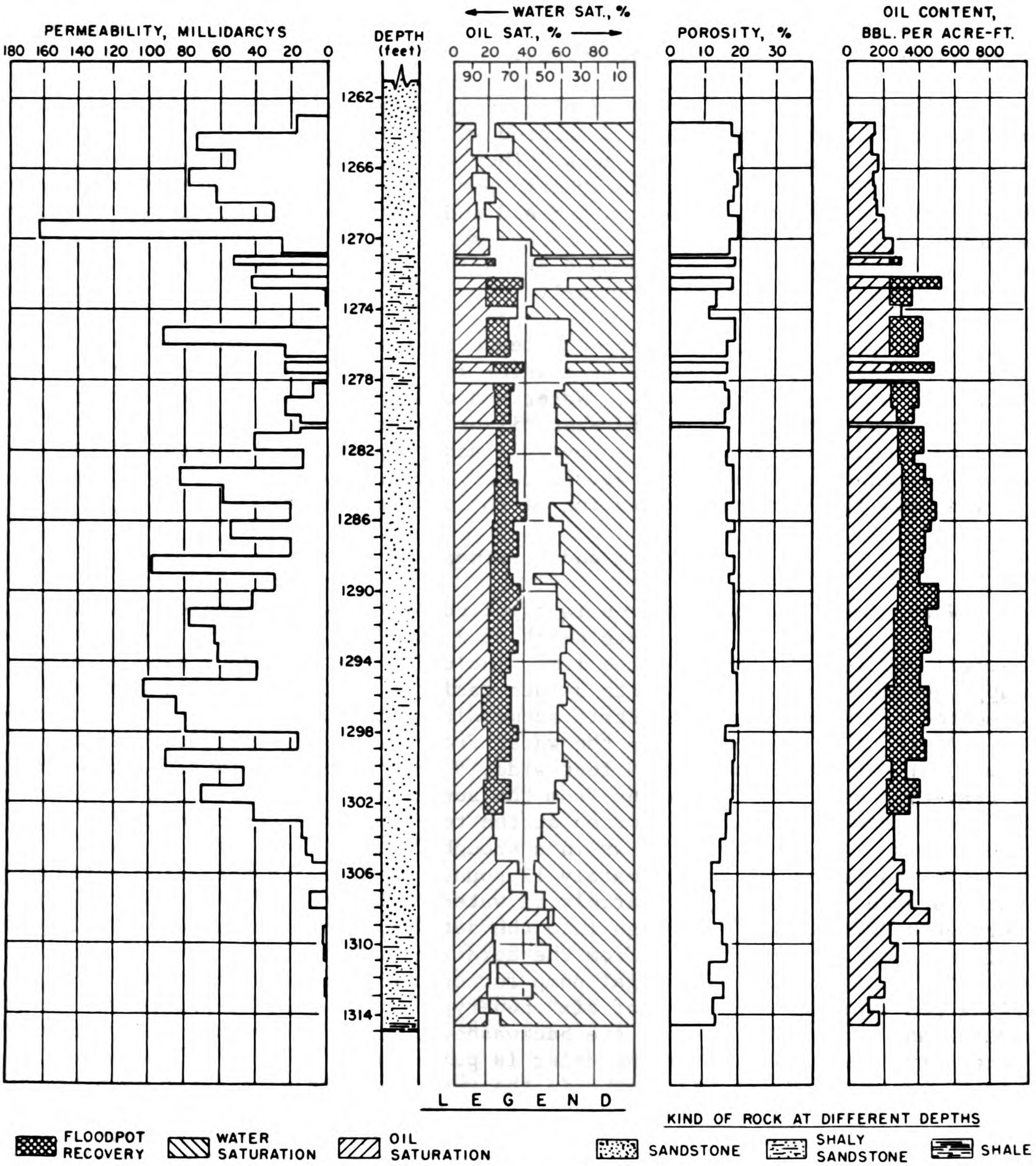

FIGURE 7. - Results of Core Analyses of Bartlesville Sandstone, Wellsville Oil Co. & Oil Recovery Corp. ORCO Process K. & S. Project, Washington County, Okla.

injecting 14 barrels of water per foot of sand at an average wellhead pressure of 220 p.s.i. Water input rates have been increasing steadily without increases of plant or wellhead pressures.

Delayed drilling of the producing wells permitted better fillup of the reservoir. The oil wells were completed with 7-inch casing set at the top of the sand and cemented with 25 sacks. They were cored to the bottom of the sand and shot with 2 quarts of nitroglycerin per foot of oil-saturated sand. They were equipped with 2 1/2-inch tubing and rods for pumping with individual gas engines. Early in the development stage some of the old wells served as test wells. These old wells were pumped by individual units and water, oil, and gas analyses were completed regularly.

Oil-metering equipment for each lease is installed at the tank battery. A dual arrangement of metering free-water knockout tanks permits each well to be tested at least once a week. Water and oil from the well are separated within tanks, and charts record when oil or water is produced. Experience with this equipment has shown an overall accuracy within 1 percent of the actual stock-tank measurement of oil runs. Other equipment at the tank battery allows for heating or treating of the oil as needed.

## Source and Treatment of Water

Water for flooding purposes is supplied by two wells completed in the Arbuckle formation at an average depth of 2,547 feet. Brine is produced from several aquifers in the Arbuckle lime, including the Roubidoux sand. These supply wells were completed with 8-inch casing set at about 1,665 feet and cemented to the surface. Electric submersible pumps, hung on 5 1/2-inch pipe at a depth of 1,860 feet, pump the water from the supply wells over an aerating tower. The redwood tower is 9 feet wide, 9 feet long, and 14 feet high and is a tray-type aerator. Raw water from the supply wells and produced brine from the lease tank batteries are mixed at the top and percolate through the aeration trays. Aerated water flows in a trough from the base of the tower to the treating house, where approximately 12 pounds of lime and potassium permanganate is added to each 1,000 barrels of water. The treated water then flows through a baffled mixing trough into the settling pond. This pond, divided by baffles, allows the products from the aeration and chemical reactions to settle out of the water. A centrifugal pump forces the treated water from the settling pond through a battery of six open-type wooden filters packed with graded gravel and sand. The filters are backwashed approximately once a day or when necessary. From the filter the water is pumped into the top of a deoxidizing tower, where the dissolved oxygen in the water is partly replaced by nitrogen. The wooden deoxidizing tower is about 6 by 20 feet and has several built-in wooden trays. The water entering at the top flows down over the trays, while nitrogen from the $CO_2$ plant bubbles up through it. This procedure reduces the dissolved oxygen content of the treated water more than 50 percent. No attempt is made to remove all the oxygen by using pressured nitrogen or vacuum deaeration. The water from the deoxidizing tower flows into a 1,000-barrel clear-water storage tank that supplies three triplex pumps. Table 3 shows the mineral analyses of the injection waters. The pumps, equipped with porcelain plungers and powered by 70-hp. gas engines, force the water to the input wells at a plant pressure of 700 p.s.i.

TABLE 3. - Mineral analyses of injection waters,
Wellsville Oil Co. & Oil Recovery Corp.
ORCO process K. & S. project,
Washington County, Okla.

| | Supply-well water | | Produced brine | | Treated water | |
|---|---|---|---|---|---|---|
| Ion or radical | P.p.m. | Reacting values, percent (Palmer) | P.p.m. | Reacting values, percent (Palmer) | P.p.m. | Reacting values, percent (Palmer) |
| Calcium (Ca)............ | 6,500 | 7.62 | 5,580 | 9.47 | 4,400 | 7.17 |
| Magnesium (Mg).......... | 1,660 | 3.20 | 1,560 | 4.36 | 1,140 | 3.06 |
| Sodium (Na)............. | 38,400 | 39.18 | 24,400 | 36.17 | 28,000 | 39.77 |
| Carbonate ($CO_3$)......... | 0 | 0 | 0 | 0 | 0 | 0 |
| Bicarbonate ($HCO_3$)...... | 323 | .12 | 550 | .31 | 202 | .11 |
| Sulfate ($SO_4$)........... | 0 | 0 | 0 | 0 | 0 | 0 |
| Chloride (Cl)........... | 75,300 | 49.88 | 51,800 | 49.69 | 54,200 | 49.89 |
| Total solids...... | 122,183 | 100.00 | 83,890 | 100.00 | 87,942 | 100.00 |
| Hydrogen sulfide ($H_2S$).. | None | | None | | None | |
| Barium (Ba)............. | 65 p.p.m. | | 389p.p.m. | | 47 p.p.m. | |
| Specific gravity, 60° F. | 1.085 | | 1.063 | | 1.070 | |

## Manufacture of Carbon Dioxide

The supply of carbon dioxide used in the ORCO process is manufactured on the flooded property. Engineers of the Oil Recovery Corp. maintain and operate the plant in conjunction with the waterflood operations of the Wellsville Oil Co. Figure 8 shows the water-treating and $CO_2$ plant. The plant is a modification of a commercial plant and was designed especially for use with this waterflood. It has a capacity of 30 tons of carbon dioxide per day and consumes about 600,000 cubic feet of natural gas.

In the process natural gas mixed with air is burned under a water-tube boiler and the carbon dioxide separated from the resultant flue gas. Steam formed in the boiler is used for power and heating in other phases of the extraction process. The flue gas at 450° F. contains about 11 percent $CO_2$. The flue gas is drawn from the boiler through a concrete tower, countercurrent to cooling water, and through a mist extractor by a steam-turbine-driven blower. From the blower the gas passes into the bottom of a steel absorber tower filled with ceramic Raschig rings and again flows countercurrent to an incoming stream of lean cool monoethanolamine (MEA). The $CO_2$ gas is absorbed by the MEA, and the remaining waste gas flows out the top of the tower. A portion of the waste gas, rich in nitrogen, is used to deoxidize the brine.

The $CO_2$-laden MEA is pumped from the bottom of the absorber tower through heat exchangers where it is warmed and then enters the top of the reactivator tower, where it flows countercurrent to steam entering at the base of the tower. The $CO_2$ gas is stripped from the MEA solution and flows out the top of the reactivator tower through a water-cooled condenser and then through a liquid separator before entering the steam-driven compressor. The hot, lean

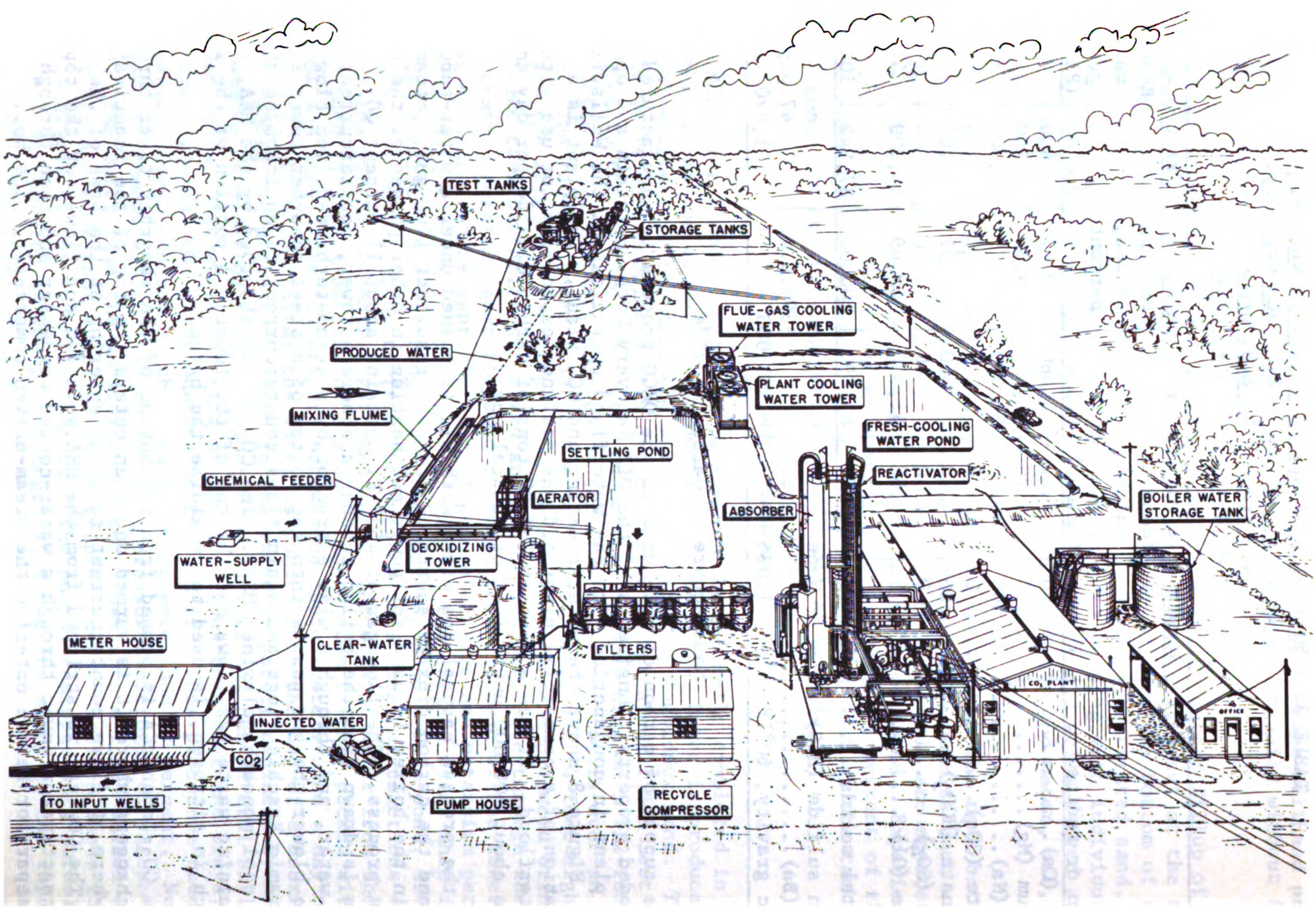

FIGURE 8. - Water-Treating and $CO_2$ Plant of Wellsville Oil Co. and Oil Recovery Corp.
K. & S. Project, Washington County, Okla.

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MEA solution is pumped from the bottom of the reactivator tower through the heat exchangers and transfers heat to the rich cool MEA solution mentioned above. From these the MEA solution passes through a water-cooled heat exchanger and back to the absorber tower to repeat the process.

A separate fresh-water system, including cooling towers, filter, and storage pond, is maintained to supply the boiler and heating system.

## Results of Flooding

This project is too new to evaluate properly, the first increase being noted in July 1958. During the last 6 months of 1958 oil production was increasing at the rate of about 2,000 barrels per month. Several oil wells have not yet been put on production, and water has not been turned into several input wells. About 50,000 barrels of oil has been recovered as a result of injecting more than 1.5 million barrels of water. This is a water-injected to oil-produced ratio of about 31 : 1. Based on experience with several waterfloods in the Mid-continent area developed without the use of carbon dioxide, the operator believes that carbon dioxide injection has helped immeasurably on this project and that it is 6 months in advance of a project using only water.

## Summary of Operations

### Wellsville Oil Co. & Oil Recovery Corp. ORCO process, K. & S. project, Washington County, Okla.

Location - secs. 5 and 6, T. 27 N., R. 13 E.
Sand flooded - Bartlesville.
Depth to top of sand - 1,300 feet.
Average sand thickness - 33 feet.
Productive area - 240 acres.
Area flooded - 190 acres.
Well pattern - 5-spot (660 x 660 ft.)

Type of water - brine.
Type of system - open.
First water injection - February 1958.
First oil increase - July 1958.
Status - active.
Gravity of oil - 33° API.
Viscosity of oil - 6.3 cp. at 100° F.

Oil production, by years, bbl. (240 acres)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1905[1].... | - | 1915...... | 13,440 | 1925...... | 4,663 | 1951[3].... | 2,696 |
| 1906...... | 37,974 | 1916...... | 11,064 | 1926...... | 4,628 | 1952[3].... | 6,982 |
| 1907...... | 39,336 | 1917...... | 10,560 | 1927...... | 3,120 | 1953[3].... | 9,134 |
| 1908...... | 45,374 | 1918...... | 9,912 | 1928...... | 3,255 | 1954[3].... | 15,556 |
| 1909...... | 36,176 | 1919...... | 7,986 | 1929...... | 3,434 | 1955[3].... | 13,627 |
| 1910...... | 39,752 | 1920...... | 5,526 | 1930...... | 3,640 | 1956[3].... | 12,990 |
| 1911...... | 47,344 | 1921...... | 5,591 | 1931...... | 3,581 | 1957[3].... | 11,732 |
| 1912...... | 34,896 | 1922...... | 5,856 | 1932...... | 3,061 | 1958...... | [4]50,703 |
| 1913...... | 28,496 | 1923...... | 5,286 | 1933...... | 1,206 | | |
| 1914...... | 17,104 | 1924...... | 5,266 | 1934[2].... | 252 | | |

[1] Production data not available for 1905.

[2] Leases abandoned.

[3] Production attributed to redrilling and early pilot waterflooding operations.

[4] 49,611 barrels attributed to ORCO process; 1,092 barrels to pilot flood.

## Summary of waterflood performance

| Date | Acres flooded | Active oil wells | Active input wells | Oil recovery, bbl. per acre | Cumulative water injected-oil produced ratio |
|---|---|---|---|---|---|
| 1958 | | | | | |
| February.... | 30 | 11 | 8 | 27 | 18 |
| March....... | 70 | 11 | 13 | 25 | 46 |
| April....... | 80 | 11 | 15 | 34 | 74 |
| May......... | 110 | 11 | 20 | 36 | 84 |
| June........ | 110 | 11 | 22 | 48 | 90 |
| July........ | 120 | 15 | 22 | 60 | 87 |
| August...... | 120 | 15 | 22 | 90 | 72 |
| September... | 120 | 15 | 22 | 135 | 50 |
| October..... | 125 | 15 | 23 | 207 | 43 |
| November.... | 130 | 15 | 24 | 285 | 36 |
| December.... | 190 | 16 | 29 | 261 | 31 |

| | Bbl. |
|---|---|
| Water injected to January 1, 1959.................................. | 1,517,909 |
| Water injected per acre (190 acres)................................ | 7,989 |
| Oil recovered to January 1, 1959................................... | 49,611 |
| Oil recovered per acre (190 acres)................................. | 261 |
| Oil recovered by primary methods to 1935 (240 acres)............... | 437,779 |
| Oil recovered per acre (240 acres)................................. | 1,824 |
| Oil recovered by pilot flood (240 acres)........................... | 73,809 |
| Oil recovered ber acre by pilot flood (240 acres).................. | 308 |
| Total oil recovered (240 acres) to February 1, 1958................ | 511,588 |
| Oil recovered per acre (240 acres) to February 1, 1958............. | 2,131 |
| Oil recovered by ORCO process (240 acres) to January 1, 1959...... | 49,611 |
| Oil recovered per acre by ORCO process (240 acres) to January 1, 1959........................................................ | 207 |

## Monthly record of water and $CO_2$ injected and oil and water produced

| Month | 1958 | | | |
|---|---|---|---|---|
| | Water injected, bbl. | Oil produced, bbl. | $CO_2$ injected, tons | Water produced, bbl. |
| January.................. | | | | |
| February................. | 14,577 | 820 | 0 | |
| March.................... | 65,588 | 905 | 0 | |
| April.................... | 122,694 | 1,023 | 65 | |
| May...................... | 130,109 | 1,220 | 457 | |
| June..................... | 145,995 | 1,336 | 566 | |
| July..................... | 143,353 | 1,885 | 645 | |
| August................... | 151,707 | 3,583 | 929 | *2,227 |
| September................ | 141,371 | 5,471 | 575 | 3,231 |
| October.................. | 201,973 | 9,642 | 418 | 5,122 |
| November................. | 200,337 | 11,192 | 667 | 6,521 |
| December................. | 200,205 | 12,534 | 683 | 8,005 |
| Total.............. | 1,517,909 | 49,611 | 5,005 | 25,106 |

* Not measured before August.

## American Climax Petroleum Corp. Childers Unit Project

In February 1957 the American Climax Petroleum Corp. began waterflooding the Childers unit in secs. 36, T. 27 N., R. 16 E., 31, T. 27 N., R. 17 E., 1, T. 26 N., T. 16 E., and 6, T. 26 N., R. 17 E., Delaware-Childers field, Nowata County, Okla. The Childers unit was formed in 1956 from 14 leases at the eastern edge of the Delaware-Childers field that were unitized to form the Childers unit for waterflooding purposes. Figure 9 shows a map and the production history of the Childers unit. Some unique features of this flood are the results from delayed drilling and fracturing of oil wells and the automatic custody transfer of oil to the pipeline.

The formation flooded is the Bartlesville sand, which occurs at an average depth of 640 feet, with an average net thickness of 29 feet. Analyses of cores cut before the flood was developed showed that the formation had the following average reservoir conditions: Porosity, 22 percent; permeability to air, 100 millidarcys; oil saturation, 30 percent; and water saturation, 35 percent. The oil produced has an API gravity of 36.5° and a viscosity of 3 cp. at 100° F.

### History Before Flooding

The leases were originally drilled in 1906 and 1907 and in 1907 reached a peak rate of oil production of more than 610,000 barrels annually. In 1913 vacuum was applied generally throughout the area. The effect of the application of vacuum was noticed the first year, when oil-production rates from the leases were increased appreciably; however, during the next few years the rate of oil production declined rapidly. Vacuum was discontinued in 1932 by mutual agreement among the operating companies.

Although the injection of air and gas into the adjacent leases effected a slight increase in the rate of oil production from the leases in the Childers unit in 1932, the rate of oil production was not substantially increased until 1934, when the first compressor plant was built and put into operation on the leases of the Childers unit. Air-gas injection was applied successfully until 1956, when the plant was dismantled in preparation for waterflooding. The early history, sand characteristics, and results of air-gas injection in the eastern part of the Delaware-Childers field were described in a report by Johnston and Riggs.12/

### Method of Completing and Operating Wells

Following unitization of the Childers leases late in 1956, all of the old producing wells were carefully plugged and abandoned and new wells drilled. The input wells were completed by setting 10 to 20 feet of 8-inch surface pipe and drilling with air to the top of the sand. The formation was drilled through and shot and the hole cleaned out. A rag or burlap packer on 2-inch,

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12/ Johnston, K. H., and Riggs, C. H., Secondary-Recovery Practices and Oil Reserves in the Eastern Part of the Delaware-Childers Field, Nowata County, Okla.: Bureau of Mines, Rept. of Investigations 4019, 1946, 50 pp.

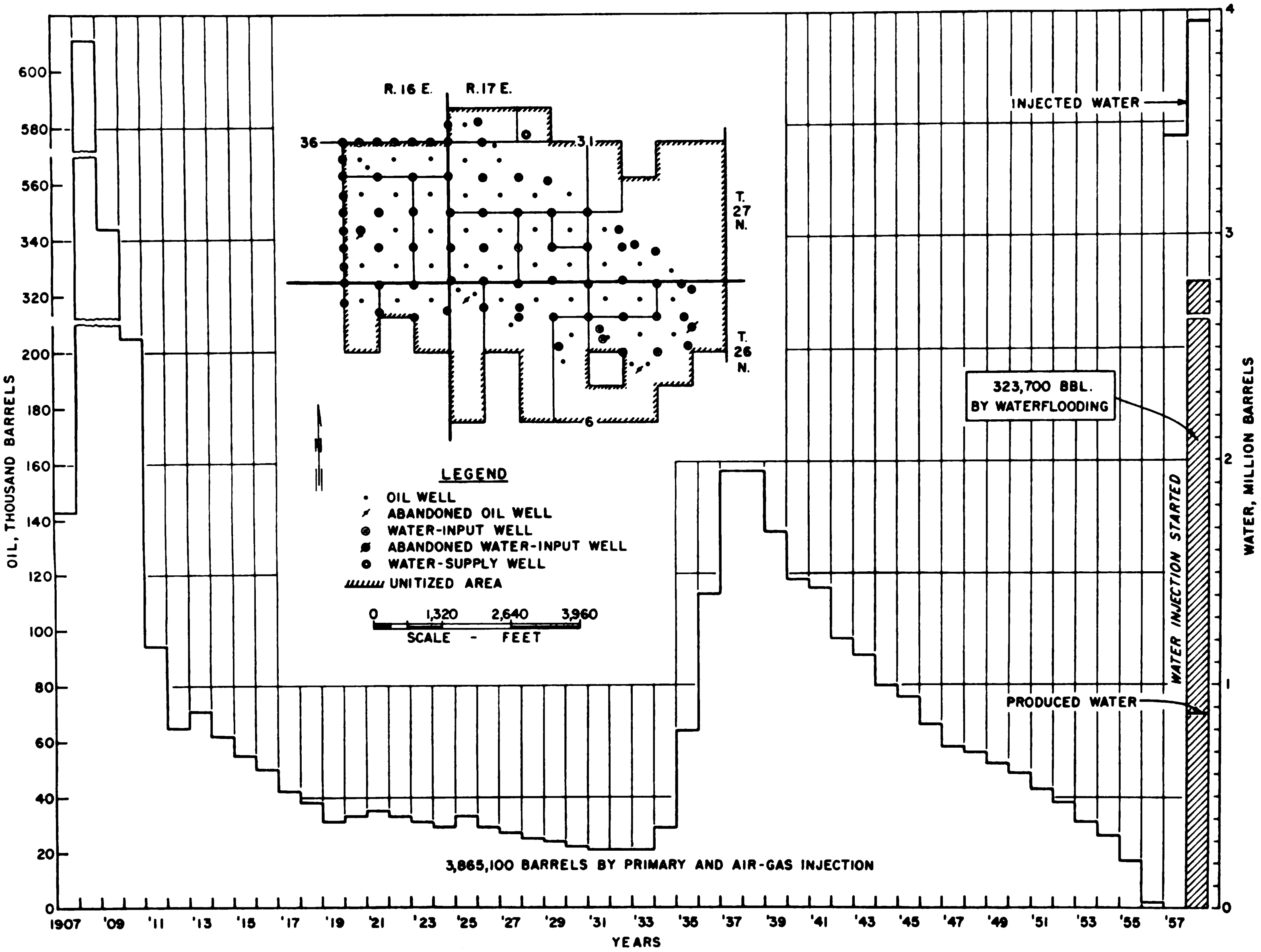

FIGURE 9. - Map and Production History of American Climax Petroleum Corp. Childers Unit, Nowata County, Okla., Jan. 1, 1959.

cement-lined pipe was set at the top of the pay sand and cemented with 20 sacks of cement. Each well was shot with 3 quarts of nitroglycerin per foot of pay sand. The meters and control valves for the input wells were in separate meter houses, so that each meter house controls approximately one-third of the meters required for the unit.

The producing wells were drilled similarly to the input wells, except that 6 5/8-inch pipe was set at the top of the oil sand and cemented with 15 sacks of cement. Because a delayed drilling method of producing was practiced, the core hole in each well was filled with cement until the fillup period of water injection was completed. The oil producers were then opened with a small air rotary rig, and the well was completed by hydraulic fracturing. The fracture treatment consisted of 3,000 to 6,000 pounds of sand and 2,000 to 3,000 gallons of oil.

The oil-producing wells were originally equipped with small electric submersible pumps, automatically controlled. The control system consisted of 3/8-inch plastic tubing hung in each well at approximately the same depth as the electric pump. The raising or lowering of the fluid level in the well changed the pressure within the tubing and actuated a sensitive pressure off-on switch at the surface; the switch controlled the electric pumps. The fracture treatment permitted removal of larger volumes of fluid from the reservoir than was anticipated; consequently, the controls were removed, and the pumps were operated continuously.

For the purpose of control the producing area is divided into three areas similar to the water-injection area, with four 210-barrel test tanks at each meter house. All of the oil wells are connected into a header to permit a 24-hour production test of each well or combination of wells having fluid production rates less than 210 barrels daily. Figure 10 is a drawing of the manifold and the test tanks.

A 6-inch oil line delivers the production from the header into one of three 560-barrel wooden receiver tanks at the main tank battery. Figure 11 shows the water-treating plant and the automatic custody transfer system used on the lease. Production from the other test tanks flows into one of the other two receiver tanks for the first stage of dehydration or water knockout. Three 4-inch lines carry the oil from the receivers to an 800-barrel redwood tank for the second stage of water separation. For fire protection a high-pressure waterline is connected into all of the receiver tanks. The water forms a spray for cooling and aids in carrying the oil to an emergency sump.

The produced brine from the first and second water-knockout points flows into a 600-barrel wooden skimming tank and into a skimming pond and finally into the treating pond for aeration. Here it is mixed with the Arbuckle brine and chemically treated for reinjection.

The oil flows through the water-separating system and through either a heater or directly into a 200-barrel steel surge tank. The surge tank is connected by a transfer pump and a manifold to two automatic metering units. The surge tank is equipped with three float switches. One, about 14 inches from the bottom of the tank, starts the circulating pump and acts as a safety

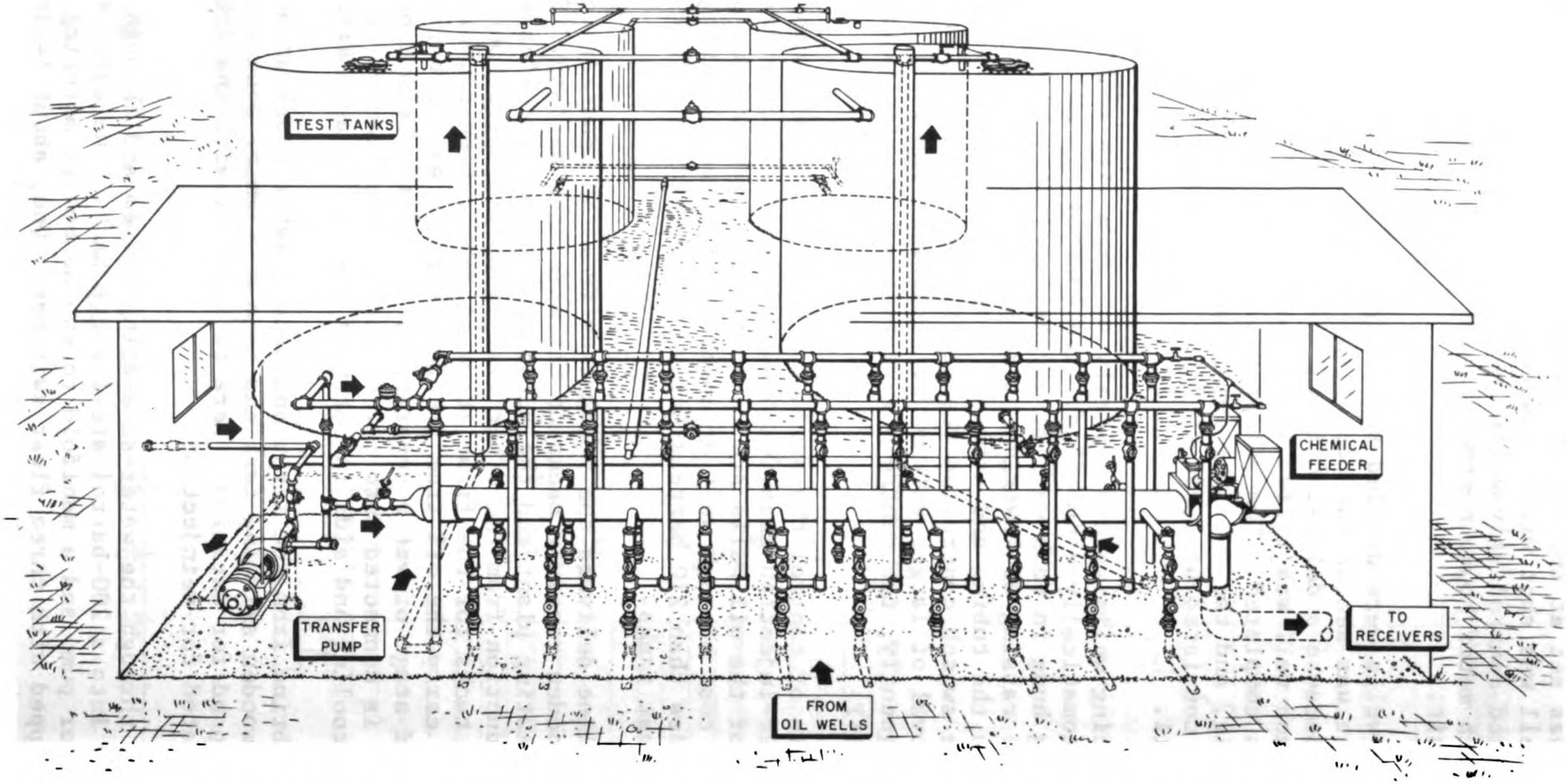

FIGURE 10. - Individual Oil-Well Testing Manifold and Tanks, American Climax Petroleum Corp. Childers Unit, Nowata County, Okla.

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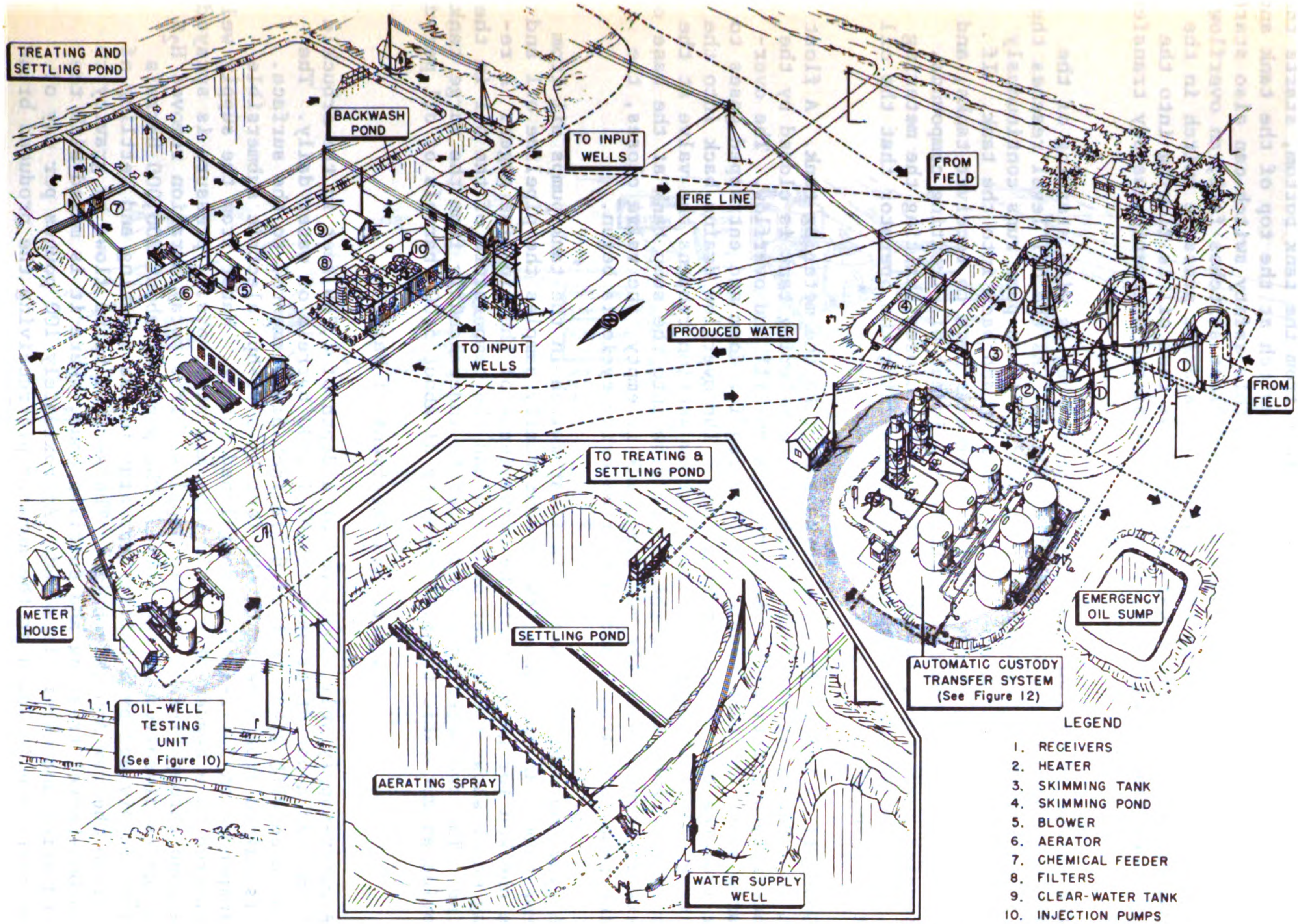

FIGURE 11. - Water-Treating Plant and Automatic Custody Transfer System of American Climax Petroleum Corp. Childers Unit, Nowata County, Okla.

switch; the second float switch, about 7 feet from the tank bottom, starts the metering cycle; the third switch is a safety switch at the top of the tank and operates only when the second switch fails. This safety switch can also start the metering cycle. If the second and third float switches fail, an overflow into the standby stock tanks is provided. A separate pressure switch in the overflow actuates a siren to warn the operator that oil is flowing into the standby stock tanks. Figure 12 is a drawing of the automatic custody transfer system.

The automatic custody transfer of the oil begins with starting of the transfer pump and opening of the shutoff valve. As the oil level reaches the first float switch, a circulating pump starts. This pump runs continuously and sends the oil through a B. S. & W. monitor and back into the tank. If bad oil is detected, a threeway valve diverts it back to receiver tanks, and a chemical pump is automatically started to inject oil-treating compounds. The transfer pump stops, and the shutoff valve closes, halting the metering cycle. The monitor also actuates a siren, warning the operator that the oil is not merchantable.

Good oil is pumped from the surge tank into the metering tank. A float switch in a recess at the bottom neck of the metering tank is closed by the oil entering, permitting the metering tank to fill and overflow. The overflow area above the tank provides a time lag for foam and entrapped gases to escape from the oil in the metering tank. The overflow drains back into the surge tank. A float switch in the overflow section reopens the valve at the bottom of the tank, allowing the oil to flow into the sump tank at the base of the metering tank. When the metering tank is empty, the valve closes, the transfer pump is started, and another metering cycle is begun.

A pipeline pump activated by a float switch in the tank pumps oil from the sump tank. An automatic device continually samples the pipeline oil and may be checked for grindout at the convenience of the pipeline gager. A recording meter shows the number of dumps and the temperature of the oil in the pipeline. The two metering systems operate independently from the surge tank to provide an automatic transfer capacity of about 5,000 barrels of oil per day.

## Source and Treatment of Water

A water-supply well, completed at a depth of 1,769 feet in the Arbuckle formation, has a potential capacity of 16,000 barrels of water daily. The well is cased with 1,480 feet of 6 5/8-inch pipe cemented to the surface. Water is raised from a depth of 500 feet by a 75-hp. electric submersible pump suspended on 5 1/2-inch, cement-lined tubing. Water from the supply well is delivered to a header of plastic pipe and at 30 p.s.i. pressure is sprayed into a pond through 1-inch plastic nipples. This spray aeration removes $H_2S$ and $CO_2$ gases dissolved in the brine. The pond, of about 200,000 barrels capacity, is divided by a baffle that aids in the aerating and settling of solids from the raw Arbuckle brine. The aerated brine flows by gravity to the 170,000-barrel treating and settling pond, where it is mixed with the produced brine and chemicals added. Approximately 100 pounds per day of calcium carbonate is added at the aerator pit receiving the produced brine

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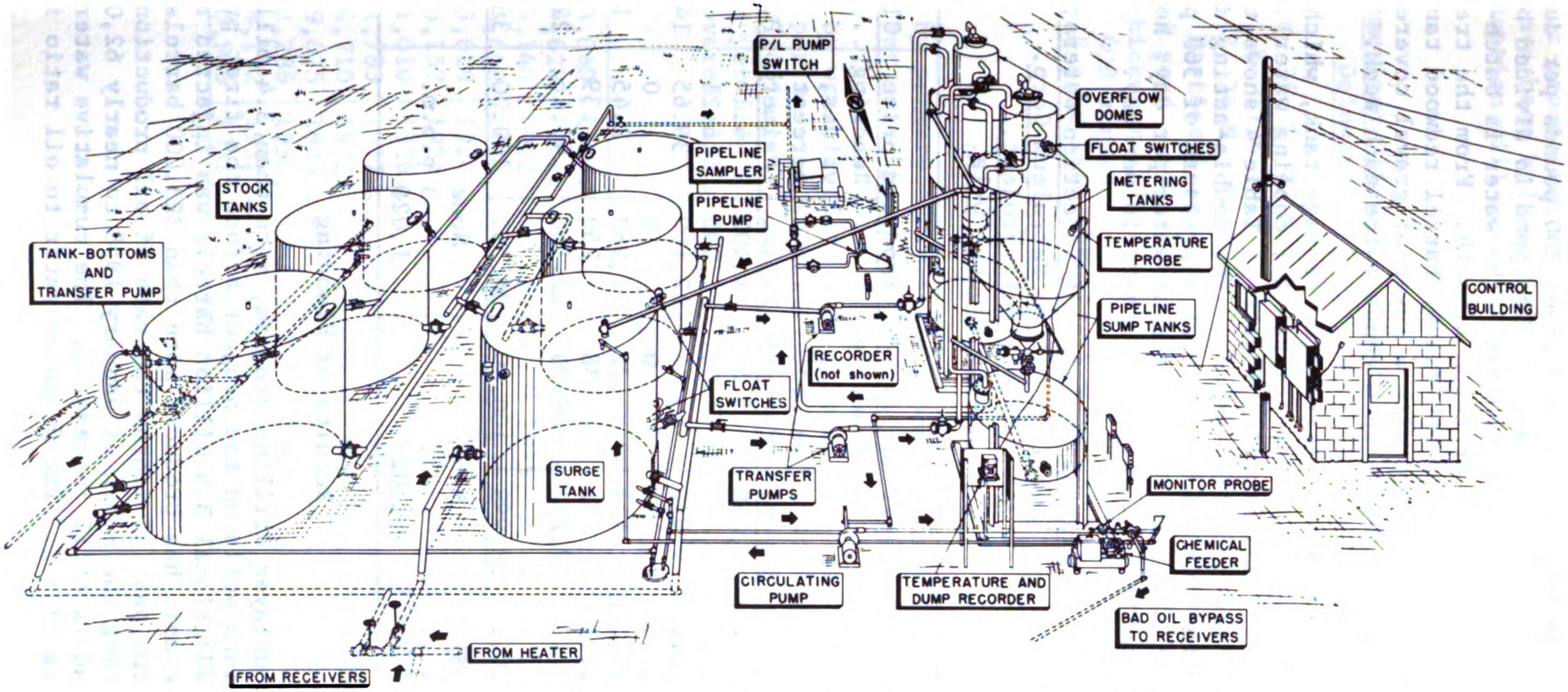

FIGURE 12. - Automatic Custody Transfer System, American Climax Petroleum Corp. Childers Unit, Nowata County, Okla.

Original from THE OHIO STATE UNIVERSITY

to obtain carbonate supersaturation, and about 200 pounds per day of ferric sulfate is added as a flocculating agent. The pond is divided by a series of baffles, which aid in the settling process. The water is batch-treated with a bactericide and corrosion inhibitor twice a month. From the treating and settling pond the water is pumped through six 67-barrel redwood tank filters. These open-type filters are packed with a layer of gravel covered with crushed anthracite. The filters are backwashed about twice each week.

Filtered water flows into a clear-water storage tank, which is a covered concrete pit (formerly used as a storage pit for cooling water). This tank has a capacity of about 2,300 barrels of water. Table 4 shows the results of a mineral analysis of the injection waters. Two double-acting duplex pumps force the water into the injection system at a pressure of 560 p.s.i. Present output of the plant is about 11,000 barrels of water per day; however, the plant has a rated capacity of nearly 15,000 barrels per day.

TABLE 4. - Mineral analyses of injection waters,
American Climax Petroleum Corp.
Childers Unit project,
Nowata County, Okla.

| | Aerated Arbuckle water supply | | Produced brine | | Clear-well water | |
|---|---|---|---|---|---|---|
| Ion or radical | P.p.m. | Reacting values, percent (Palmer) | P.p.m. | Reacting values, percent (Palmer) | P.p.m. | Reacting values, percent (Palmer) |
| Calcium (Ca)........... | 1,098 | 5.51 | 1,100 | 4.14 | 180 | 0.70 |
| Magnesium (Mg)......... | 123 | 1.02 | 1,000 | 6.21 | 24 | .15 |
| Sodium (Na)............ | 9,930 | 43.47 | 12,100 | 39.65 | 14,500 | 49.15 |
| Carbonate ($CO_3$)........ | 0 | 0 | 0 | 0 | 0 | 0 |
| Bicarbonate ($HCO_3$)..... | 434 | .72 | 1,982 | 2.45 | 1,013 | 1.29 |
| Sulfate ($SO_4$).......... | 181 | .38 | 250 | .39 | 309 | .50 |
| Chloride (Cl).......... | 17,232 | 49.90 | 22,160 | 47.16 | 22,000 | 48.21 |
| Total solids...... | 28,998 | 100.00 | 38,592 | 100.00 | 38,026 | 100.00 |
| Hydrogen sulfide ($H_2S$). | None | | None | | None | |
| Barium (Ba)............ | do. | | 3 p.p.m. | | Do. | |
| Specific gravity 60° F. | 1.023 | | 1.029 | | 1.028 | |

### Results of Flooding

By following a delayed drilling program, more than 3.4 million barrels of water was injected into wells on the project before the first producing well was completed. An additional 3.9 million barrels was injected after production was begun. The unit has produced more than 323,000 barrels of oil by waterflooding. In the past 12 months the rate of oil production has increased from 861 barrels during the month of January 1958 to nearly 62,000 barrels per month in December and is still increasing. The cumulative water-injected to oil-produced ratio is 23 : 1. The produced-water to oil ratio is 2.7 : 1.

The peak rate of production has not been reached and because all oil wells on this project have been hydraulically fractured, the future rates of both oil and water production will be of special interest.

### Summary of Operations

### American Climax Petroleum Corp. Childers Unit project
### Delaware-Childers field, Nowata County, Okla.

Location - secs. 36, T. 27 N., R. 16 E., 31, T. 27 N., R. 17 E., 1, T. 26 N., R. 16 E., 6, T. 26 N., R. 17 E.
Sand flooded - Bartlesville.
Depth to top of sand - 640 feet.
Average sand thickness - 29 feet.
Area flooded - 408 acres.
Well pattern - 5-spot (660 x 660 ft.).
Type of water - Arbuckle brine.
Type of system - open.
First injection - February 1957.
First increase - January 1958.
Status - active.
Gravity of oil - 36.5° API.
Viscosity of oil - 4.5 cp. at 100° F.

### Data to January 1, 1959

| | Bbl. |
|---|---|
| Oil recovered by primary and air-gas injection (455 acres) | 3,865,121 |
| Oil recovered per acre by primary and air-gas injection (455 acres) | 8,495 |
| Oil recovered by waterflooding (408 acres) | 323,752 |
| Oil recovered per acre by waterflooding (408 acres) | 794 |
| Water injected (455 acres) | 7,404,741 |
| Water injected per acre (455 acres) | 16,274 |
| Total oil recovered (455 acres) | 4,188,873 |

### Oil produced by years, bbl.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1907 | 143,060 | 1920 | 32,612 | 1933 | 21,139 | 1946 | 65,535 |
| 1908 | 610,628 | 1921 | 34,900 | 1934 | 29,462 | 1947 | 58,430 |
| 1909 | 344,144 | 1922 | 32,843 | 1935 | 63,618 | 1948 | 56,078 |
| 1910 | 205,446 | 1923 | 31,365 | 1936 | 113,355 | 1949 | 52,497 |
| 1911 | 93,619 | 1924 | 29,167 | 1937 | 157,488 | 1950 | 49,126 |
| 1912 | 65,157 | 1925 | 32,706 | 1938 | 156,989 | 1951 | 43,160 |
| 1913 | 71,010 | 1926 | 29,073 | 1939 | 134,665 | 1952 | 38,315 |
| 1914 | 61,783 | 1927 | 26,587 | 1940 | 118,294 | 1953 | 31,377 |
| 1915 | 54,710 | 1928 | 25,055 | 1941 | 114,898 | 1954 | 25,680 |
| 1916 | 49,625 | 1929 | 24,170 | 1942 | 97,009 | 1955 | 16,597 |
| 1917 | 42,286 | 1930 | 22,277 | 1943 | 90,651 | 1956 | 1,860 |
| 1918 | 38,192 | 1931 | 20,624 | 1944 | 80,198 | 1957 | 0 |
| 1919 | 30,986 | 1932 | 21,029 | 1945 | 75,637 | 1958 | 323,752 |

### Summary of waterflood performance

| Date | Acres flooded | Active input wells | Active oil wells | Oil recovery, bbl. per acre | Cumulative water injected-oil produced ratio |
|---|---|---|---|---|---|
| Dec. 31, 1957........ | 408 | 53 | 0 | 0 | - |
| Dec. 31, 1958........ | 408 | 72 | 51 | 794 | 23 |

### Monthly record of water injected and oil produced, bbl.

| Month | 1957 | | | 1958 | | |
|---|---|---|---|---|---|---|
| | Water injected | Oil produced | Water produced | Water injected | Oil produced | Water produced |
| January......... | | | | 359,319 | 861 | 4,836 |
| February........ | *422,296 | | | 301,610 | 1,304 | 5,600 |
| March........... | 175,722 | | | 317,990 | 1,694 | 13,662 |
| April........... | 331,602 | | | 338,428 | 10,112 | 32,850 |
| May............. | 364,981 | | | 357,951 | 14,689 | 44,035 |
| June............ | 295,260 | | | 328,004 | 19,039 | 41,580 |
| July............ | 353,014 | | | 319,648 | 28,208 | 59,641 |
| August.......... | 317,741 | | | 314,726 | 37,955 | 90,917 |
| September....... | 246,002 | | | 302,226 | 37,536 | 104,832 |
| October......... | 342,891 | | | 315,191 | 52,328 | 140,362 |
| November........ | 294,743 | | | 331,047 | 58,205 | 149,063 |
| December........ | 302,994 | | | 371,355 | 61,821 | 186,256 |
| Total...... | 3,447,246 | 0 | 0 | 3,957,495 | 323,752 | 873,634 |

* Includes cumulative total of water injected into boundary wells.